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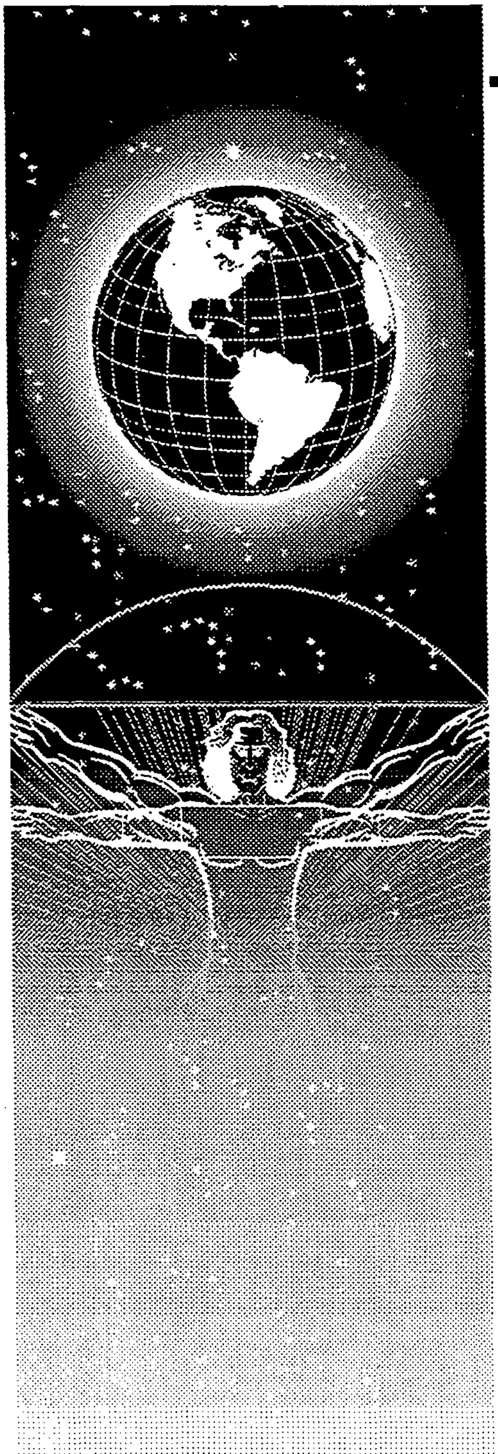

UNITED STATES AIR FORCE RESEARCH LABORATORY

TPH CRITERIA WORKING GROUP FIELD DEMONSTRATION: HARRIER JET CRASH SITE, FAIRBORN, OH

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

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13. ABSTRACT *(Maximum 200 words)*
The site of a Harrier jet crash near Wright-Patterson Air Force Base, Ohio, was selected as a demonstration site for the Total Petroleum Hydrocarbon Criteria Working Group approach. The Working Group approach assesses total petroleum hydrocarbon (TPH) mixtures in 13 fate and transport fraction as and applies best available toxicity criteria to each of the fractions to develop Risk Based Screening Levels (RBSLs). The resulting petroleum release at the crash site consisted of JP-8 jet fuel and was limited to surface soil. The impacted soil was exposed to environmental conditions for two weeks prior to sampling, allowing evaporative, photo and some biological weathering to occur. The residential and commercial RBSLs developed using the Working Group protocol were approximately 4 and 11 times here, respectively, than those determined using the Category 3 levels indicated by the Ohio EPA Guidance for Emergency Response. The RBSLs developed for this site were especially suitable due to the lack of carcinogenic polycyclic aromatic hydrocarbons, benzene, toluene, ethylbenzene or xylenes. The Working Group approach not only can result in cost saving due to more reasonable cleanup levels, but it also provides a much better understanding of the remaining constituents in a complex weathered mixture.

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PREFACE

This effort was performed by Operational Technologies Corporation (OpTech) under U.S. Air Force Contract Number F41624-94-D-9003/008. OpTech activities were conducted under the Project Management of Mr. Erik Vermulen, 1370 North Fairfield Road, Suite A, Beavercreek, Ohio 45432. Major Steve Channel of the Operational Toxicology Branch, Human Effectiveness Directorate, Air Force Research Laboratory (AFRL/HEST) served as contract monitor.

The author gratefully acknowledges Libby Domingue of the 88th Air Base Wing (ABW) Environmental Management at Wright-Patterson Air Force Base, Ohio, for her assistance in collecting samples and providing site data. We also acknowledge Richard Enz and Del Schumaker of Lancaster Laboratories, Lancaster, Pennsylvania, for analytical results.

LIST OF ABBREVIATIONS AND ACRONYMS

AF	Attenuation Factor
atm	atmosphere
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
BUSTR	Bureau of Underground Storage Tank Regulations
C	number of Carbon atoms in hydrocarbon molecule
cm	centimeter
c.s.	chemical specific
C_{sat}	soil saturation Concentration
DRO	Diesel Range Organics
EC	Effective Carbon number of chemical molecule
FID	Flame Ionization Detector
f_{oc}	fraction of organic carbon in soil
ft	feet
g	gram
GC	Gas Chromatograph
GRO	Gasoline Range Organics
H_c	Henry's law constant
kg	kilogram
K_{oc}	carbon-water sorption coefficient
k_s	soil-water sorption coefficient
L	liter
mg	milligram
MS	Mass Spectrometer
NAPL	Non-Aqueous Phase Liquid
ND	Nondetect
OHM	OHM Remediation Services Corporation
PAH	Polycyclic Aromatic Hydrocarbon
PF	Partitioning Factor
ppm	parts per million
RBCA	Risk Based Corrective Action
RBSL	Risk Based Screening Level
RES	Residual Saturation
RfD	Reference Dose
s	second
S	Solubility
Std. Dev.	Standard Deviation
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbon
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
WPAFB	Wright-Patterson Air Force Base
yr	year

TPH CRITERIA WORKING GROUP FIELD DEMONSTRATION: HARRIER JET CRASH SITE, FAIRBORN, OH

1.0 INTRODUCTION

This report presents the results of a Tier 1 ASTM Risk-Based Corrective Action (RBCA) analysis conducted to demonstrate the development of risk-based cleanup criteria for petroleum-impacted soils. The work is part of a series of field demonstrations to assess the effectiveness of the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG or Working Group) protocol for evaluating risks from different types of weathered fuel releases in various soil types. This report evaluates soils impacted by a JP-8 jet fuel release resulting from a Harrier jet crash.

On October 16, 1997 a Marine AV8b Harrier jet taking off from Wright-Patterson Air Force Base (WPAFB) crashed. WPAFB emergency vehicles arrived on-site along with WPAFB Environmental Management personnel. WPAFB requested a response team from OHM Remediation Services Corporation (OHM) to assess and remediate the resulting contamination.

Approximately two weeks following the crash, samples were collected and submitted by OHM for total petroleum hydrocarbon (TPH), polyaromatic hydrocarbons (PAH) and benzene, toluene, ethylbenzene and xylene (BTEX) analyses to identify the zone of contamination for remediation. The Working Group requested additional samples for fractionation analysis, which were collected one day later. For comparison of results from the different analytical methods used, an effort was made to collect the samples for fractionation analysis from approximately the same locations submitted for conventional TPH analysis. Because the samples collected for conventional TPH and fractionation analyses were not duplicates, a statistical correlation between the Working Group analytical method and the conventional TPH analytical method could not be performed. The results of both sets of data are compared in Section 4.0. Due to the release occurring on private property, impacted soils were excavated within weeks, based on Ohio Environmental Protection Agency (EPA) emergency petroleum cleanup criteria.

1.1 Objectives

This site was not a typical selection for a field demonstration. Due to the unforeseen occurrence of this release and the emergency response for sampling and remediation, time was not allotted for development of a sampling plan. However, it provided an opportunity to characterize the hydrocarbon fraction composition of a JP-8 release, which had not been analyzed in previous demonstrations. In addition, it provided an opportunity to demonstrate the effectiveness of the Working Group protocol on a site with surficial petroleum contamination.

To develop risk-based criteria, soils from the site were analyzed by the analytical method recommended by the Working Group to characterize the petroleum present as concentrations of of 13 TPH fractions. The results of these analyses were then input to simple fate and transport models for soil exposure pathways provided in the RBCA guidance document (ASTM, 1995). Because this was a relatively fresh release and data indicated that only surficial soil was impacted, groundwater samples were not collected for fractionation analysis. Therefore, soil exposure pathways only were evaluated for this demonstration. The primary goals of this study were:

1. Demonstrate the Working Group methodology,
2. Compare the calculated risk-based levels to current state cleanup levels, and
3. Evaluate the variability in the risk-based levels developed for the site.

It is important to note that while the cleanup criteria derived in this analysis were compared to state of Ohio criteria for emergency response actions, this analysis was not intended for use in modifying the current TPH cleanup criteria established by the state for the site.

1.2 Overview of RBCA

The RBCA framework integrates "site assessment, remedial action selection and monitoring with U.S. EPA-recommended risk and exposure assessment practices" (ASTM, 1995), allowing the user to make corrective action decisions for different sites in a consistent manner which is protective of human health and the environment. The core elements of the RBCA framework are an understanding of:

- The characteristics of the source contamination,
- The pathways through which contaminants move in the environment, and
- The existing and potential receptors exposed to the contaminants.

These elements are incorporated into a three-tiered approach that involves increasingly sophisticated levels of data collection and analysis. The initial assessment, Tier 1, uses conservative assumptions, some of which are replaced in later tiers (i.e., Tiers 2 and 3) by less conservative site-specific assumptions. The soil cleanup goals defined for each tier may be less costly to achieve than those defined by the previous tier. Upon completion of each tier, the user reviews the results and decides if the cost of conducting additional site-specific analyses for the next tier are warranted by the potential reduction in cost associated with a reduced remediation plan. Hence, the RBCA approach is more cost-effective than traditional approaches under which all sites, regardless of site-specific conditions, are required to conform to uniform standards and procedures.

1.3 Overview of Working Group Approach

The Working Group approach presently focuses only on human health, addressing both carcinogenic and non-carcinogenic impacts. The approach recognizes that TPH is comprised of different types or classes of hydrocarbons that differ in chemical structure (i.e., aliphatic or aromatic). The classes of hydrocarbons possess distinct physical and toxicological characteristics which vary widely and contribute to the overall fate, transport and toxicological characteristics of the TPH mixture. The risk associated with the TPH mixture as a whole is determined by combining the risks associated with individual fractions present in accordance with their percent composition in the TPH mixture.

The Working Group approach relies on the separation of petroleum into 13 separate fractions, listed in Table 1-1. These fractions are based upon the physical structure of the compounds (aromatic or aliphatic) and the "equivalent carbon number" (EC), which is a function of boiling point, and are determined by the retention time on a gas chromatography (GC) column relative to n-alkanes of known carbon numbers. Retention time is directly related to the boiling points of the different hydrocarbons. Order of magnitude differences in partitioning properties were used as the basis of fraction cutoffs. The fractions have been assigned specific toxicological, fate and transport characteristics that are based upon an extensive review of available data for individual compounds and for petroleum mixtures which are representative of the fraction. The rationale for fraction cutoffs is discussed in detail in a document prepared by the Working Group, "Selection of Representative TPH Fractions Based on Fate & Transport Considerations" (TPHCWG, 1998a).

TABLE 1-1 WORKING GROUP AROMATIC AND ALIPHATIC FRACTIONS

Aromatic Fraction	Aliphatic Fraction
EC 5–7 (Benzene)	EC 5–6
EC >7–8 (Toluene)	EC 6–8
EC >8–10	EC >8–10
EC >10–12	EC >10–12
EC >12–16	EC >12–16
EC >16–21	EC >16–21
EC >21–35	

Note: EC - equivalent carbon fractions are determined by the retention time on a GC column, relative to n-alkane compounds of known carbon numbers

Within a framework such as the American Society for Testing and Materials' (ASTM's) RBCA, the toxicity, fate and transport information defined by the Working Group may be used to perform a risk-based analysis of each fraction within the petroleum mixture. The fraction-specific analyses are then used to develop soil and groundwater cleanup levels which are protective of human health. More details on the Working Group approach is provided in Section 3 of this document.

1.4 Site Description

The crash site was located just off the eastbound ramp to I-70 from northbound 675 in Fairborn, Ohio, approximately 11 miles northeast of Dayton, Ohio (Figure 1-1). The impacted area was approximately 55 feet long by 21 feet wide. An estimated 7000 pounds of JP-8 jet fuel was on-board at the time of the crash. Land use surrounding the site is primarily agricultural.

The site represented a "single spill" location with varying concentrations of relatively "fresh" JP-8 in soil; however, within the two weeks between the accident and sample collection, some volatilization and both photo- and biodegradation is expected to have occurred. Due to the emergency nature of this release and the fact that the crash occurred on private property, soil excavation was planned within the following weeks. Therefore, tiered assessments would not be necessary and geotechnical data were not collected. Surficial soil at the site was described as a blackish silty loam. The average total organic carbon (TOC) of the background samples collected was 20,900 mg/kg. Moisture content was approximately 13.5 percent (see Appendix A for laboratory results).

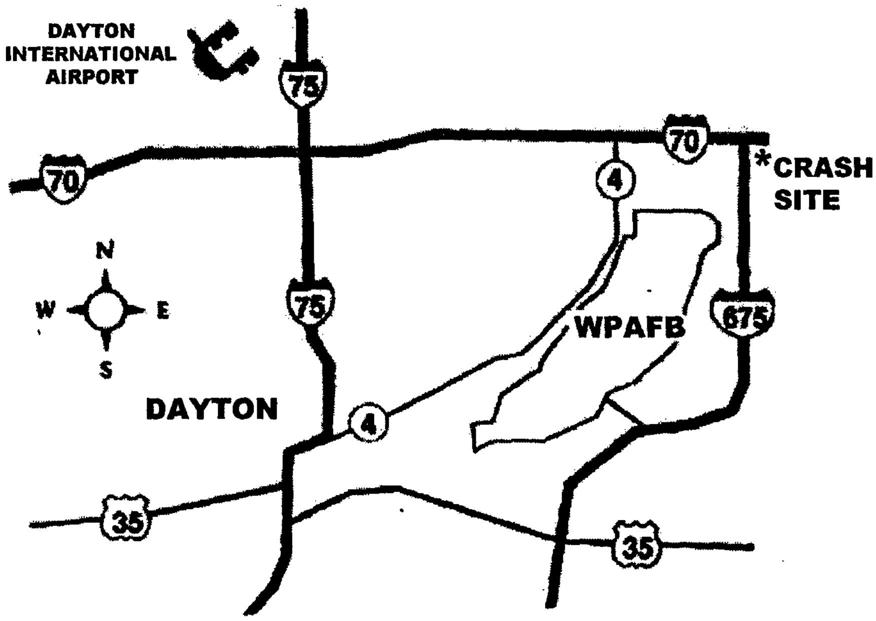

Figure 1-1 Crash Site Location

2.0 SAMPLING AND ANALYSIS

2.1 Soil Sample Collection

Samples for this demonstration project were collected as a separate effort from the sampling conducted by OHM. As described earlier, soil samples collected by OHM, approximately two weeks after the crash, were submitted for BTEX, PAH and TPH analysis. BTEX and PAH levels did not exceed regulatory limits. No benzene was detected. Ethylbenzene ranged from 0.042 to 4.1 ppm. Toluene levels ranged from nondetect (ND) (with a detection limit <0.27 ppm) to 1.6 ppm. Xylene levels ranged from 0.36 to 25 ppm. PAH were below detection limits with the exception of one naphthalene hit of 9.4 ppm. TPH levels ranged from 3100 to 18,000 ppm, exceeding a regulatory standard of 904 ppm, and therefore necessitated excavation of impacted soils (OHM, 1997).

Surface soil samples collected for this effort were taken from six of the same locations sampled the previous day by OHM (see Figure 2-1) at depths of approximately 1 to 2 feet below ground surface (bgs). The sample numbers are assigned by location relative to a utility pole near the site. For example IW20S25-008 indicates a location at the impact site that is 20 feet west and 25 feet south of the utility pole. The last three digits, -008, designate the sampling sequence. Samples with a BE designation were taken in an area adjacent to, but unaffected by the aircraft impact.

Sample locations chosen for fractionation analysis were based on the highest Photo-Vac™ flame ionizing detector (FID) readings and are presented in Table 2-1. Soil was collected using a shovel and spoon, apportioned into four-ounce sample jars with minimal headspace, stored on ice and shipped overnight to Lancaster Laboratories, Lancaster, Pennsylvania, for fractionation analysis. Background soil were submitted for TOC analysis and matrix spikes. Approximately one month later, during excavation of impacted soil, the water table was encountered at a depth of 7 feet bgs. At this point, excavation was stopped and water samples were taken which resulted in no detectable contamination.

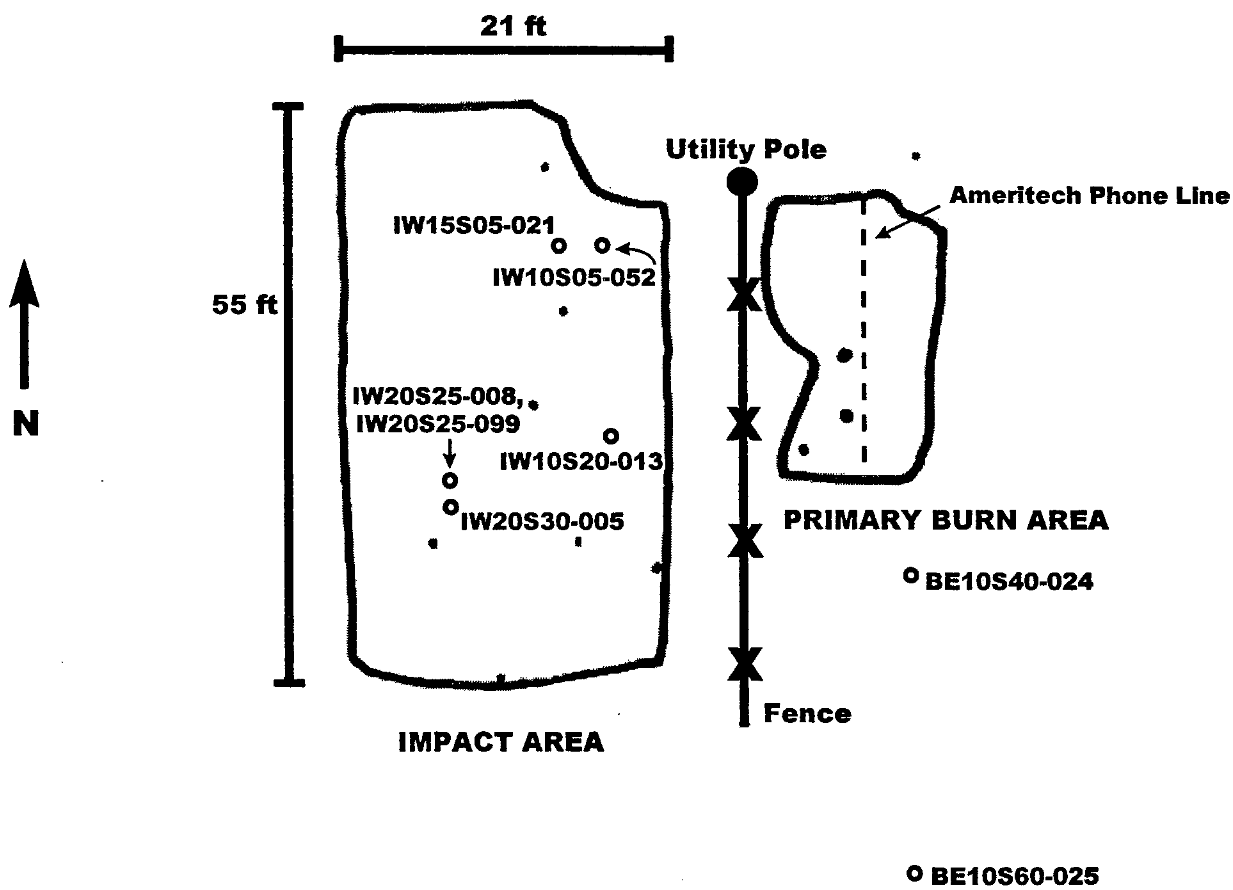

Figure 2-1 Site Locations of Fractionated Samples

TABLE 2-1 SAMPLES SELECTED FOR FRACTIONATION ANALYSIS BASED ON HEADSPACE ANALYSIS

Sample Number	Depth	Head space (ppm)	Direct Method	TOC and MS	Lab Sample #
IW20S25-008	0-6"	617	yes		2813057
IW20S25-099	6-12"	959	yes		2813058
IW15S05-021	0-6"	544	yes		2813059
IW10S35-004	0-6"	202			
IW10S05-052	0-6"	433	yes		2813060
IW10S20-013	0-6"	681	yes		2813061
IW20S20-011	0-6"	290			
IW20S30-005	0-6"	346	yes		2813062
BE10S60-025	0-6"	7		yes	2813063
BE10S40-024	0-6"	11			

Notes: Head space analysis preformed by a Micro-FID (Photo Vac™)
MS = matrix spike
blanks indicate that sample was not selected for analysis

2.2 Analytical Approach

Cleanup levels based on TPH assume that a result generated using a conventional TPH method (e.g., EPA 8015) is an accurate measurement of the hundreds of petroleum-derived constituents within the mixture, and that measurement is associated with a known level of risk. Often TPH cleanup criteria are based on the most toxic constituents found in TPH mixtures (e.g., benzene, benzo(a)pyrene, etc.). This criteria is then applied to the measured concentration, regardless of the presence or absence of toxic constituents within the site-specific TPH concentration. Conventional TPH measurements do not reflect the compositional changes that occur from weathering and complex matrix interference, particularly for soil analysis. Health risks cannot be assessed without an accurate description of constituents in the mixture and the toxicity of those constituents.

Several analytical techniques are available for measuring TPH in the environment. Many methods are designated by the range of compounds they analyze, such as gasoline range organics (GRO) and diesel range organics (DRO). Identifying the method with a particular petroleum product is often only useful to indicate a specific carbon range for the method. As an example, GRO methods typically quantify over a hydrocarbon range of C6 through C10 or C12 and standardize against gasoline. A gasoline standard may be used to quantify other hydrocarbon products present in this range (e.g., naphthas, light mineral spirits or Stoddard solvent), but the presence of gasoline-range hydrocarbons in a sample does not indicate that gasoline is actually present. JP-8 jet fuel spans both the typical gasoline (C6 through C12) and diesel (C12 through C24) carbon ranges. Using either a gasoline or a diesel method to identify JP-8 may be misleading since a part of this petroleum mixture is present in each of these ranges, resulting in some overlap and overestimation of TPH concentrations.

Some methods measure more of the TPH present than other methods due to more rigorous extraction techniques or more efficient solvents. Methods based on infrared, such as EPA Method 418.1, are also subject to interference from naturally-occurring organic materials including peat moss or humic material present in topsoil. This interference may result in predictions of higher TPH concentrations than are actually present.

Therefore, cleanup criteria based on single TPH measurements do not correlate well to risk. The same concentration of TPH at two different sites may represent very different mixtures. One may include carcinogenic hydrocarbons while the other doesn't. An accurate assessment of risk is based on an understanding of the toxicological effects of the compound(s) present in the environmental media. As a result, many TPH criteria were based on aesthetics, analytical method reporting limits or other non-risk based criteria, in conjunction with an assessment of carcinogenic indicator compounds. Criteria, not based on risk, may lead to unnecessary remediation in many instances. It is important to note, however, that human health risk is not always the driving factor in establishing cleanup levels. In some cases, aesthetics, ecological risk or other criteria may determine appropriate cleanup levels.

Two TPH analytical procedures were performed on samples from the site. Unfortunately, as mentioned earlier, the samples were not collected as duplicates to allow for statistical comparison between TPH analytical methods. The conventional method conducted on the samples collected by OHM was based on GC analysis of the whole hydrocarbon mixture present. Another set of six samples, taken from six of the same approximate sampling locations, was submitted for analysis using the Working Group Direct Method. Background soil was submitted for TOC analysis and matrix spikes. The Direct method was developed by Shell Developmental Company specifically for use with the Working Group protocol. It provides results grouped into the 13 TPH fractions designated in the protocol.

2.2.1 Direct Method

The Direct Method uses a tiered analytical approach to determine values for TPH fractions in the C6 to C28 range. The sample is extracted and analyzed using GC with flame ionization detector to obtain a direct TPH measurement. This analysis can also be used to determine the type of hydrocarbons present or to "fingerprint" the type or types of contamination. If the profile of fractions from the samples are similar (i.e, site appears to be homogenous), a few may be chosen for further characterization by separation of aliphatic and aromatic fractions, which are then analyzed in a manner similar to the whole extract (ie., GC/FID).

The aliphatics and aromatics are separated prior to the single GC/FID analysis, using alumina (modified EPA Method 3611B) or silica gel (modified EPA Method 3630B or C), which can be used to fractionate petroleum materials into saturates, aromatics and polars. The Direct Method is similar to these methods except that a smaller column is used to minimize dilution and *n*-pentane is used for extraction and to elute the aliphatics. The use of n-pentane instead of n-hexane allows for the determination of TPH starting at and including n-hexane (EC-6). Methylene chloride is used to elute aromatics from alumina and a mixture of methylene chloride and acetone is used for elution of aromatics from silica gel.

Following separation of the aromatics and aliphatics on the alumina or silica gel column, fractionated extracts are analyzed by GC/FID. In cases where light-end constituents (i.e., EC<9) are observed, a GC/mass spectrometer (MS) is utilized, especially for the quantitation of BTEX.

Typically only a few samples from the site need to be analyzed using Direct Method to identify the TPH fraction concentrations at the site. If the TPH fraction concentrations are similar across the site, the fingerprint may be used to establish cleanup criteria and less expensive conventional methods may be used to characterize the extent of contamination. In addition, application of traditional EPA analytical methods is likely to be necessary to quantify the presence of indicator hydrocarbons, such as BTEX and PAH. The Working Group's Volume 1 "Analysis of Petroleum Hydrocarbons in Environmental Media" includes a concise discussion of analytical methods currently available for use in evaluating petroleum contaminated soils and waters (TPHCWG, 1998b).

2.2.2 Conventional TPH Methods

The conventional TPH methods used by OHM during the initial site characterization included Gasoline Range Organics by EPA Method Modified 8015A, Method 8100 for Modified for Diesel Range Organics by GC/FID and Method 8260 A, GC/MS for Volatile Organics. EPA Method 8015 uses methylene chloride extraction but has no prescribed carbon ranges for quantitation. If gasoline is suspected, the TPH method will use purge/trap sample introduction. If heavier petroleum fractions are the contaminants, direct injection and hot oven temperatures are used. The GC-based methods usually cannot quantitatively detect compounds below C6. Therefore, it may be less of a problem with weathered product; however, GC-based methods may overestimate TPH concentrations due to the detection of non-petroleum compounds, such as chlorinated solvents.

2.2.3 Quality Control Analysis

To verify the recovery of individual aliphatic and aromatic hydrocarbon fractions, duplicate spike analyses were performed on a background sample, collected near but outside the impacted area. The results were compared to acceptable matrix spike recoveries for semi-volatile organic constituents in soil using U.S. EPA Method 8270.

3.0 WORKING GROUP RISK ASSESSMENT APPROACH

The first step in the Tier 1 assessment was the identification of contaminant sources, transport mechanisms, exposure pathways and potential receptors based on existing site information. Carcinogenic indicators (benzene and PAHs) were not detected in the soil sampled. Therefore, for purposes of establishing cleanup criteria for soil only noncarcinogenic risk was calculated. Risk-based screening levels (RBSLs) were then calculated for each exposure pathway by applying the TPH fractionation results and the procedures established by the Working Group. The approach used for calculating TPH RBSLs differs from that used in a typical ASTM RBCA (1995) analysis in that it incorporates the concepts of additivity of risks (for the TPH mixture), chemical saturation concentrations (C_{sat}) and residual saturation (RES). Treating TPH as a mixture is especially important for consideration of fate, transport and toxicological interactions between different individual chemicals or fractions.

Noncarcinogenic risks for each fraction is represented by the hazard quotient (HQ), which is the ratio of the estimated daily intake of a contaminant in given media (ie., soil) to a reference dose (RfD) as follows:

$$HQ_i = \frac{C_{iTPH}(^{mg}/_{kg}) \times IntakeRate(^{mg}/_{kg-day})}{RfD_i(^{mg}/_{kg-day})}$$

The intake rate depends upon the frequency and duration of exposure, as well as the source concentration and the transport rates between the source and the receptor, for cross media pathways. Additivity is incorporated into the calculation of a "whole TPH" hazard index (HI) and RBSL by apportioning the total risk (i.e., HI = 1 for the mixture) over the different fractions present. That is, rather than each fraction assuming risk equal to a HQ of 1, each fraction would be allotted a portion of the risk, with the sum of the HQs from each fraction less than or equal to the HI of 1 for the mixture as depicted in the equation below.

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i} \leq 1$$

where:

HI	=	Hazard Index (typically ≤ 1) [unitless]
n	=	number of fractions (13 total) [unitless]
HQ_i	=	Hazard Quotient for each specific fraction [unitless]
f_i	=	Percent Weight of each TPH fraction in "whole TPH" mixture [unitless]
C_{TPH}	=	Concentration of "whole TPH" [mg/kg]
RBSL	=	Tier 1 risk-based screening level for a TPH fraction [mg/kg]

The assumption of additivity for calculating a mixture RBSL for TPH is highly conservative because the toxicological information for the target fractions indicates that these fractions impact different organs (see section 3.2). Typically, additivity is appropriate for constituents or constituent classes which impact the same organ.

For cross media pathways where transport and therefore exposure are maximized at the saturation concentration for specific fractions, the following equation is solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = Min\left(\sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i}, \sum_{i=1}^{i=n} \frac{C_{isat}}{RBSL_i}\right) \leq 1 \quad \text{given,}$$

$$\sum_{i=1}^{i=13} f_i = \sum_{i=1}^{i=n} \frac{C_i}{C_{TPH}} = 1 \quad \text{where,}$$

where:

$C_{i\,sat}$	=	Saturation concentration for each TPH fraction [mg/kg]

The C_{sat} serves as an upper exposure limit for cross media pathways. It represents the chemical concentration in soil at which the sorption limits of the soil particles, the solubility limits of the soil pore water and the saturation limit of the soil pore air have been reached. A concentration above the C_{sat} does not indicate the presence of mobile, free-phase chemicals. Actual mobility of non-aqueous phase liquid (NAPL) depends on product and soil properties which are characterized by various capillary, gravitational, hydrodynamic and surface tension forces. However, at soil concentrations greater than C_{sat}, the likelihood of free phase NAPL should be considered. The calculation for C_{sat} is defined as:

$$C_{sat}\left[{}^{mg}\!/_{kg}\right] = \frac{S}{\rho_s} * [H_c\theta_{as} + \theta_{ws} + k_s\rho_s]$$

where:

S	=	Water Solubility [mg/L]
ρ_s	=	Soil Bulk Density [g/cm^3]
H_c	=	Henry's Law Constant [cm^3/cm^3]
θ_{as}	=	Volumetric air content of the soil [cm^3/cm^3]
θ_{ws}	=	Volumetric water content of the soil [cm^3/cm^3]
k_s	=	Soil-water sorption coefficient ($k_s = K_{oc} x\ f_{oc}$) [cm^3/g]

Although this equation is defined for chemicals in the environment as pure compounds, it is also valid for chemicals present in mixtures, as long as no separate NAPL is also present. When the total soil concentration exceeds C_{sat}, Raoult's law governs the composition of the chemical mixture in the vapor and water phases in soil. Raoult's law states that the concentrations of chemicals in the vapor and water phases, in equilibrium with soil at concentrations greater than saturation, are functions of the mole fraction of each contaminant in the separate hydrocarbon phase. This will result in calculated C_{sat} values lower than those predicted using the above equation since both the pore water and pore air contaminant concentrations will be adjusted based on the mole fraction of each contaminant present.

The C_{sat} limit does not apply to direct exposure pathways such as the surface soil contact pathway, since the exposure is to the original impacted media (i.e., contaminated soil), rather than to the cross media to which the soil contamination has been transferred.

A similar term which is sometimes confused with C_{sat} is residual saturation, abbreviated RES. When calculating an RBSL or SSTL, a value of RES means that the selected risk level (e.g., HI=1) could not be reached or exceeded for the pathway and scenario given the constituents present, regardless of the contaminant concentration. A value of RES is obtained at the TPH concentration where the C_{sat} of the mixture is reached (i.e., each fraction has reached C_{sat}). When calculating a "whole TPH" RBSL, this means that even if the concentration of each fraction is set equal to C_{sat} for that fraction and pathway, the combined risk associated with each fraction still does not equal a HI of "1."

3.1 Fraction-specific Physical Properties

As mentioned earlier, the 13 fractions selected by the Working Group were based on order of magnitude differences in partitioning properties. First the hydrocarbons were divided into chemicals of a similar nature (i.e., aromatic and aliphatic) and then boiling point ranges, which correspond to the EC numbers, were used to further separate different fractions. The fraction-specific properties may then be used to estimate the partitioning of each specific fraction in the environment, using either simple or complex fate and transport models. Hence, the fraction is treated like a single chemical for modeling purposes. The fractions allow a more accurate estimation of exposure to the complex mixture than can be modeled from single TPH measurements.

Chemical properties which specifically govern how a chemical interacts with its environment include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. The fraction-specific values for these parameters are provided in Table 3-1. A discussion of the role that each of these parameters plays in basic partitioning in a soil/water/air system is provided in the next section.

TABLE 3-1 TPH FRACTIONS DERIVED FROM FATE AND TRANSPORT CHARACTERISTICS AND ASSOCIATED PROPERTIES (BASED ON AN EQUIVALENT CARBON NUMBER[1])

	Solubility (mg/L) S	Henry's Law Constant H_c	Molecular Weight (g/mole)	Vapor Pressure (atm)	log K_{oc}	PF[2] (soil/water)	PF[2] (soil/vapor)
Aliphatics							
EC5-EC6	3.6E+01	3.4E+01	8.1E+02	3.5E-01	2.9E+00	1E+01	3E-01
>EC6-EC8	5.4E+00	5.1E+01	1.0+02	6.3E-02	3.6E+00	4E+01	9E-01
>EC8-EC10	4.3E-01	8.2E+01	1.3E+02	6.3E-03	4.5E+00	3E+02	6E+00
>EC10-EC12	3.4E-02	1.3E+02	1.6E+02	6.3E-04	5.4E+00	3E+03	5E+01
>EC12-EC16	7.6E-04	5.4E+02	2.0E+02	4.8E-05	6.7+E00	7E+04	1E+03
>EC16-EC35	1.3E-06	6.4E+03	2.7E+02	7.6E-06	9.0E+00	1E+07	1E+05
Aromatics							
EC6-EC7	1.8E+03	2.3E-01	7.8E+01	1.3E-01	1.9E+00	9E-01	4E+00
>EC7-EC8	5.2E+02	2.7E-01	9.2E+01	3.8E-02	2.4E+00	2E+00	9E+00
>EC8-EC10	6.5E+01	4.9E-01	1.2E+02	6.3E-03	3.2E+00	2E+01	5E+01
>EC10-EC12	2.5E+01	1.4E-01	1.3E+02	6.3E-04	3.4E+00	2E+01	2E+02
>EC12-EC16	5.8E+00	5.4E-02	1.5E+02	4.8E-05	3.7E+00	5E+01	2E+03
>EC16-EC21	5.1E-01	1.3E-02	1.9E+02	7.6E-06	4.2E+00	1E+02	4E+04
>EC21-EC35	6.6E-03	6.8E-04	2.4E+02	4.4E-09	5.1E+00	1E+03	3E+07

Notes: Table extracted in part from TPHCWG, 1998a.
[1] Equivalent carbon number is proportional to normal boiling point.
[2] PF – Partitioning factors determine soil to water and soil to vapor concentrations at equilibrium. Values are based on pure compounds. Behavior may differ in complex mixtures.

Using the properties presented in Table 3-1, the simple partitioning of a chemical or a group of chemicals, such as the TPH fractions, may be determined using the mass balance relationships described by Feenstra *et al.* (1991). These relationships deal with partitioning between water, soil and air. Depending on the properties of the chemical and certain basic soil parameters, where a chemical will reside in the soil may be determined. Any mass of soil consists of a collection of solid particles with voids in between. These void spaces may contain water, air or a mixture of both. The method for estimating exposure for partitioning-dependent pathways is discussed in detail in Appendix B.

3.2 Overview of Toxicity Criteria for Fate and Transport Fractions

The Working Group approach focuses on human health risk, both carcinogenic and non-carcinogenic impacts. In order to assess carcinogenic risk, indicator compounds are used (benzene and the carcinogenic PAH). The assessment of non-carcinogenic risk uses the fraction-specific toxicity criteria summarized in Table 3-2. The majority of constituents in TPH are noncarcinogenic. The relative mass of each of the fate and transport fractions and concentration of carcinogenic indicators in soil may be determined using the analytical method developed by the Working Group.

Reference doses (RfDs) are estimates of daily exposure to the human population, including sensitive subgroups, that are likely to be without appreciable risk of deleterious effects during a lifetime. RfDs are developed for non-carcinogenic compounds. In some cases, the same toxicity criterion is assigned to different fate and transport fractions due to the similarity of toxicity findings across fractions or limitations in the available toxicity data. However, it is important that the fractions remain differentiated so that the exposure potential may be estimated appropriately. Combining fate and transport information with the RfDs for each fraction, fraction-specific RBSLs could be estimated for each applicable exposure scenario. These fraction-specific RBSLs may then be combined with a site-specific mixture composition to calculate a single mixture-specific TPH RBSL. A summary of the fraction-specific RfDs assigned by the Working Group is provided in Table 3-2.

TABLE 3-2 WORKING GROUP TOXICOLOGY FRACTION-SPECIFIC RFDS

Effective Carbon Range	Aromatic RfD (mg/kg/day)	Critical Effect	Aliphatic RfD (mg/kg/day)	Critical Effect
EC_5–EC_6 EC_7–EC_8	0.20 - Oral 0.10 - Inhalation	Hepatoxicity, Nephrotoxicity	5.0 - Oral 5.0 - Inhalation	Neurotoxicity
EC_9–EC_{10} EC_{11}–EC_{12} EC_{13}–EC_{16}	0.04 - Oral 0.05 – Inhalation	Decreased body weight	0.1 - Oral 0.3 - Inhalation	Hepatic and hematological changes
EC_{17}–EC_{21} EC_{22}–EC_{34}	0.03 - Oral	Decreased body weight	1.00 - Oral	Hepatic (foreign body reaction) granuloma
$>EC_{34}$	—	—	20 - Oral	Hepatic changes

Carcinogenic indicators are always evaluated separately since their presence, even in relatively low concentrations, generally drive cleanup. The hazard assessment for TPH fractions would only be used in cases where indicator compounds are not present or are present below regulatory action levels. More information on the development of the RfDs is provided in the

Working Group's Volume 4 "Development of Fraction-Specific Reference Doses and Reference Concentrations for Total Petroleum Hydrocarbons" (TPHCWG, 1998c).

In general, aromatic fractions have lower RfDs and are approximately an order of magnitude more toxic than the corresponding aliphatic fraction. These values are based on chronic effects which include hepatoxicity (liver toxicity), nephrotoxicity (kidney toxicity) and decreased body weight.

4.0 ANALYTICAL RESULTS

4.1 Direct Method Results

Typical aromatic and aliphatic fraction distributions for these field demonstration soils generated using the Direct Method are provided in Figure 4-1. The profile of TPH composition is fairly uniform throughout the site over the intervals sampled. The samples are comprised primarily of aliphatic compounds in the C10 to C16 range (Table 4-1). All of the samples contained similar profiles of hydrocarbons in the C6 to C19 carbon range, with the most likely composition of the samples being cyclic alkanes, branched alkanes and substituted aromatics, based on GC/MS analysis. There is a lack of n-alkanes and highly branched alkanes predominated the mixture. Branched alkanes are generally resistant to biodegradation. The overall weight percentage of aromatics in the weathered JP-8 was low (<15 percent of the "whole TPH"). These characteristics are fairly consistent with JP-8, but indicates some degree of photo- and biodegradation. For example, fresh JP-8 is comprised of high concentrations of cyloalkanes and n-alkanes with lower concentrations of monaromatics and branched alkanes (TPHCWG, 1998d).

The limits of quantitation for the fractions ranged from about 0.2 to 10 mg/kg for the lightest fractions to up to 604 mg/kg for the aliphatic >C21-35 range. These limits are somewhat conservative and, in several cases, petroleum hydrocarbons at lower concentrations were quantified in some of the fractions.

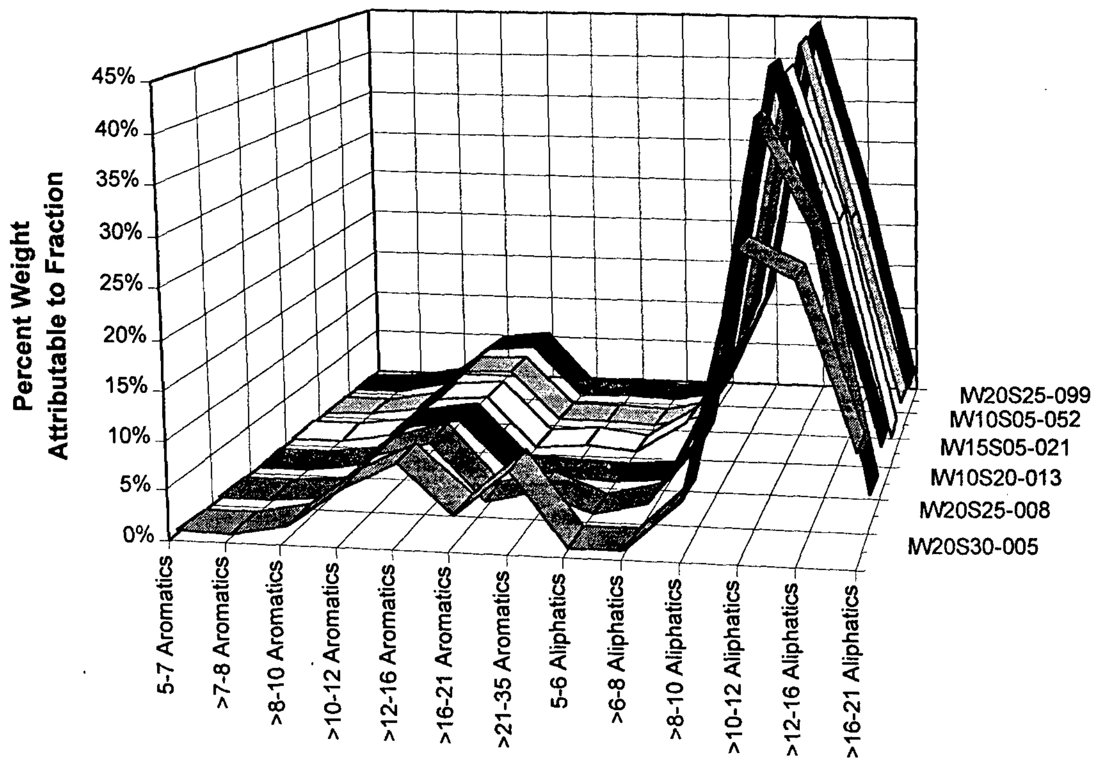

Figure 4-1 Fraction Composition: Direct Method

Note: For all non-detect values, ½ the detection limit was used to calculate fraction distributions.

TABLE 4-1 ANALYTICAL RESULTS OF TPH FRACTIONS

Sample Identification:	IW20S25-008 (mg/kg)	IW20S25-099 (mg/kg)	IW15205-021 (mg/kg)	IW10S05-052 (mg/kg)	IW10S20-013 (mg/kg)	IW20S30-005 (mg/kg)	Average % Weight
5-6 Aliphatics	<5	<10	<10	<24	<10	<2	0.0%
5-7 Aromatics (benzene)	<5	<0.2	<10	<24	<10	<2	0.0%
>6-8 Aliphatics	19	65	165	148	51	<2	1.4%
>6-8 Aromatics (toluene)	<5	1	<10	<24	<10	<2	0.0%
>8-10 Aliphatics	113	761	566	1557	1006	21	12.7%
>8-10 Aromatics	10	60	44	107	70	<10	0.9%
>10-12 Aliphatics	565	2685	2008	5150	3899	117	45.5%
>10-12 Aromatics	75	326	245	642	454	20	5.6%
>12-16 Aliphatics	414	1567	1251	2848	2239	106	26.6%
>12-16 Aromatics	96	354	266	682	531	32	6.2%
>16-21 Aliphatics	<25	65	51	<241	<242	<24	0.4%
>16-21 Aromatics	<25	<24	<25	35	41	<24	0.2%
>21-35 Aliphatics	<63	95	88	<603	<604	<60	0.6%
>21-35 Aromatics	<63	<60.0	<62	<60	<60	<60	0.0%

Note: Percent Weight represents the average percent weight of the six samples.

4.2 Comparison of Direct Method and Conventional Analytical Results

A comparison of results (samples from comparable sampling locations) obtained using the fractionation method and the conventional method is provided in Table 4-2. TPH concentrations ranged from approximately 389 to 11,657 mg/kg for samples analyzed by the Direct method. Samples, collected the prior day by OHM and analyzed by EPA Method 8015A GRO and 8100/DRO, ranged from 3,100 to 8,500 mg/kg, as analyzed. The comparable levels of total petroleum hydrocarbons observed among the samples analyzed by the Direct and those samples analyzed by the conventional method were well within an order of magnitude. Although in general, the conventional method provided higher estimates of the TPH present.

TABLE 4-2 COMPARISON OF ANALYTICAL RESULTS

Approximate Sampling Location	Direct Method (ppm)	Conventional TPH (ppm)
IW20S25 (6 inch)	1387	7800
IW20S25 (1 ft)	6028	7800
IW15S05	4742	7400
IW10S05	11657	7800
IW10S20	8757	8500
IW10S20	389	3100

5.0 RISK ASSESSMENT RESULTS AND RBSLS

As discussed in Section 3.0, the approach used for calculating TPH RBSLs differs from that used in a typical Risk analysis. Evaluation of TPH as a mixture is especially important for consideration of fate, transport and toxicological interactions between individual fractions.

The RBCA framework provides guidance and methodology for performing risk-based assessments of sites. It does not however, require that a specific approach such as the one outlined in section 3.0 and Appendix B be adopted. Incorporation of concepts such as additivity, Raoult's law and C_{sat} is appropriate for increasing the accuracy of a Tier 1 or Tier 2 assessment of TPH at a site. These concepts should be incorporated into any RBCA assessment of a TPH site using the Working Group or similar protocol.

5.1 RBCA Site Assessment Model

For the purposes of the field demonstration, the RBCA analysis conducted using the Working Group protocol was based upon a site conceptual model which assumes leaching of subsurface soil to groundwater. The area surrounding the impacted site is agricultural. Therefore direct contact with soil is probable. No residential or commercial dwellings are located immediately above or near the impacted site; however, future land use does not exclude these scenarios. Therefore, for the Tier 1 assessment, it is assumed that a residential housing unit with a potable well could be located on site immediately above impacted subsurface soils. The direct contact soil pathway was also considered, based on the assumption that individuals could come into contact with impacted surface soils during agricultural use or land development.

Both the volatilization to indoor and outdoor air pathways were not included in this analysis, as only surface soils were impacted and volatilization of lighter hydrocarbons had already occurred. Soil characterization conducted by OHM indicated that the JP-8 contamination was limited to surficial soils. In addition, the ASTM RBCA framework models volatilization from a subsurface source, which is not applicable to this site. A RBCA site assessment diagram identifying sources, pathways and receptors is provided in Figure 5-1. The RBSL model runs are provided in Appendix C.

5.1.1 Residential Scenario

The RBSLs and HIs for the residential scenario are presented in Table 5-1. The soil leaching to groundwater pathway yielded the lowest RBSLs, ranging from 3125 to 4410 mg/kg. Higher RBSLs resulted for the direct contact pathway, ranging from 5709 to 6780 mg/kg. Approximately half of the samples exceeded a HI of 1.0. This suggests that using a Tier 1 analysis, acceptable risk for a residential scenario would be exceeded at specific sampling locations at the site.

TABLE 5-1 RESIDENTIAL RBSLS

Sampling Location	"Whole TPH" (mg/kg)	Soil Leaching to Groundwater RBSLs (mg/kg)	HI	Direct Contact RBSLs (mg/kg)	HI
IW20S25-008	1387	3801	0.36	6297	0.22
IW20S25-099	6028	4392	**1.37**	6598	0.91
IW15S05-021	4742	4277	**1.11**	6780	0.70
IW10S05-052	11658	4102	**2.84**	6682	**1.74**
IW10S20-013	8757	4410	**1.99**	6697	**1.31**
IS20S30-005	390	3125	0.12	5709	0.07
Average RBSL	5494	4018	1.30	6461	0.83
Std. Dev.	4299	492	1.01	404	0.64

Note: RBSL was developed using one-half the detection limit for ND values.

5.1.2 Commercial Scenario

The exposure pathways driving RBSLs for the commercial scenario are the reverse of those driving the residential scenario RBSLs. The direct contact pathway RBSLs are consistently lower. No exceedence of acceptable risk would occur from use of groundwater given the frequency of exposure for this receptor. Only one sample slightly exceeded the target hazard index of 1.0 for the direct contact pathway.

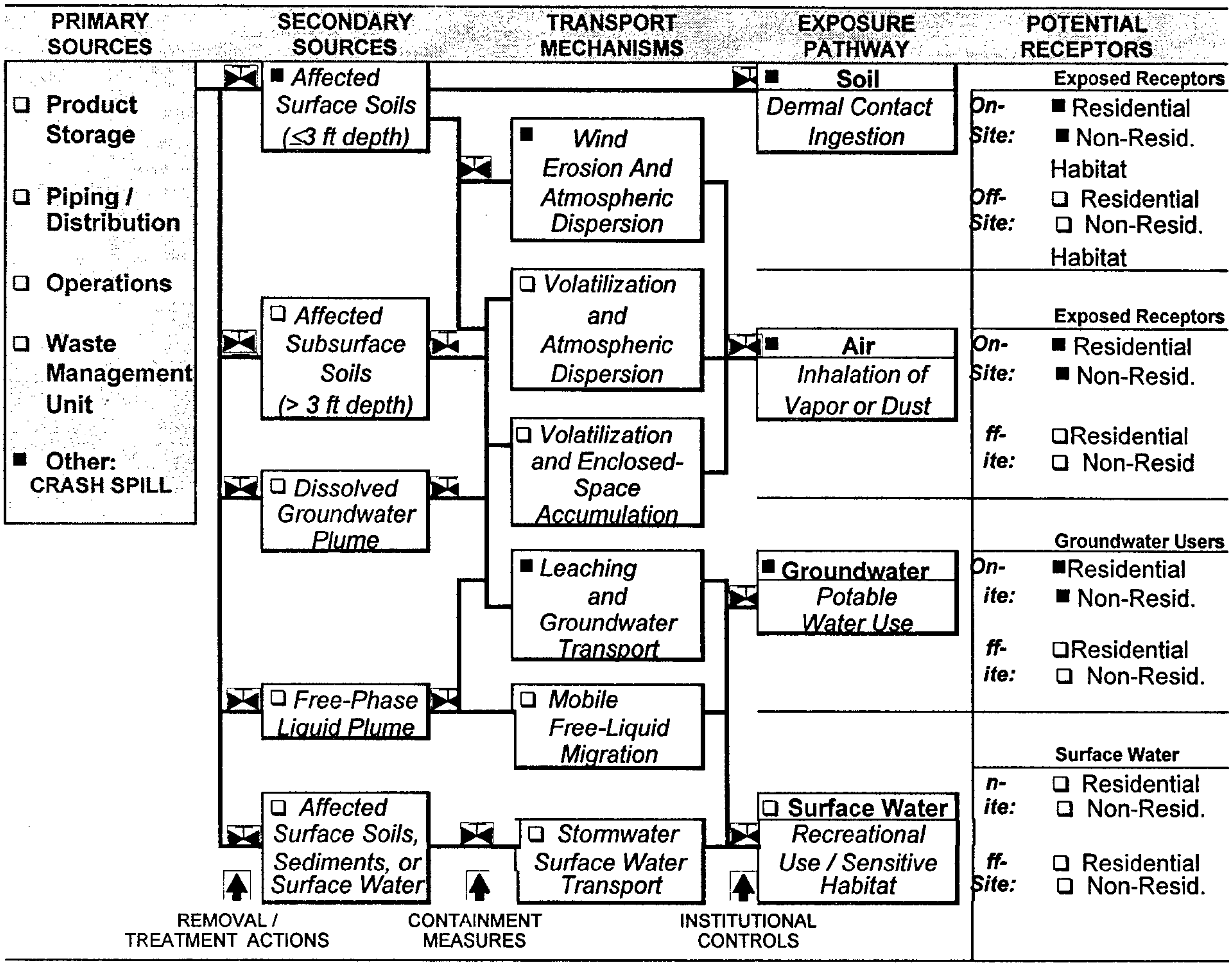

Figure 5-1 Exposure Pathway Analysis

TABLE 5-2 COMMERCIAL RBSLS

Sampling Location	"Whole TPH" (mg/kg)	Soil Leaching to Groundwater RBSLs (mg/kg)	HI	Direct Contact RBSLs (mg/kg)	HI
IW20S25-008	1387	17710	0.08	9306	0.15
IW20S25-099	6028	27955	0.22	9749	0.62
IW15S05-021	4742	20204	0.23	10019	0.47
IW10S05-052	11658	20256	0.58	9874	**1.18**
IW10S20-013	8757	26862	0.33	9897	0.88
IS20S30-005	390	11373	0.03	8442	0.05
Average RBSL	5494	20727	0.24	9548	0.56
Std. Dev.	4299	6115	0.19	596	0.43

Note: RBSL was developed using one-half the detection limit for ND values.

5.2 Comparison with Ohio Criteria

Ohio EPA offers guidance adapted from the Bureau of Underground Storage Tank Regulations (BUSTR) Corrective Actions Guidance Document for situations where a release of petroleum has occurred from a non-BUSTR regulated source (Ohio EPA, 1997). The guidance was developed specifically for emergency response actions. It may not be appropriate for use at sites where long term clean up is necessary, such as where there is extensive groundwater contamination or more than just petroleum contamination.

The guidance provides the "Site Feature Work Sheet" presented in Table 5-3 for determining petroleum cleanup standards for non-BUSTR sites. Points are assigned based on the description of each site feature. Once the points have been assigned, the total is matched with the corresponding category in the "Petroleum Action Levels Table" shown in Table 5-4.

Based on the total from the Site Feature Worksheet, a category for clean-up levels is selected (see Table 5-4). Category 3 action levels were determined for this site (904 mg/kg for TPH). TPH cleanup levels from Categories 1 to 4 vary less than an order of magnitude, from 380 to 1156 mg/kg. These levels represent emergency cleanup levels which are designed to be ultra protective.

The TPH RBSLs developed using the Working Group approach were approximately 4 to 7 times higher than the Ohio action level for residential land use. The commercial scenario RBSLs were approximately 11 to 23 times higher the Ohio Category 3 action levels. However, it is important to note that if the commercial scenario was the only viable land use for the impacted area, the Ohio site feature worksheet scoring would also have been higher, resulting in Category 4 action levels (1156 mg/kg for TPH). In that case the commercial RBSLs, developed using the Working Group approach, would be 8 to 18 times higher than the Ohio emergency action level.

TABLE 5-3 SITE FEATURE WORK SHEET

Site Features	Score 15 Points	Enter Score	Score 10 Points	Enter Score	Score 5 Points	Enter Score
1. Proximity of perimeter of spill to a public or private well or water intake	>1000 ft	15	300-1000 ft		<300 ft or inside a sole source aquifer, well head protected area or unknown	
2. Depth to ground water	>75 ft		25-75 ft		<25 ft or unknown	5
3. Predominant type of substratum	Unfractured clay, shale, claystone, mudstone, clay, silty clay, low permeable tills	15	Clayey silt, moderate permeable tilll, silty shale, unfractured siltstone-sandstone-limestone, sandy clay loam, loam, silt, sandy clay, clay loam			
4. Proximity to structures or preferential migration pathways (see below)	<8 points	15	8-12 points		>12 points	
5. Proximity to surface water and/or sensitive areas	>120 ft		50-120 ft	10	<50 ft or unknown	
6. Land use	Commercial/ Industrial				Residential/Recreation/ Agricultural	5
Add Subtotals	+	45	+	10	+	10
					Total Score =	65

Site Feature #4 Worksheet:

Structures with basements or subsurface foundations within 50 ft (4 points).	0
Water line within 50 ft (4 points).	0
Curtain drains, trench drains or field tiles within 100 ft (4 points).	0
Shallow injection wells, if within 50 ft, score 3 points, if within 100 ft, score 1 point.	0
Septic systems (tank and associated leaching systems) within 50 ft (2 points).	0
Building type structure without subsurface conditions listed above within 50 ft (1 point).	0
Sanitary sewer line with 50 ft (1 point).	0
Natural gas lines within 50 ft (1 point).	0
Pipelines or other conduits within 50 ft (1 point).	0
Buried telephone/television cable lines with 50 ft (1 point).	1
Buried electrical cable and lines with 50 ft (1 point).	1
Total	2

TABLE 5-4 OHIO EPA PETROLEUM ACTION LEVELS

Constituent	Category 1	Category 2	Category 3	Category 4
Total Score	<45 points	46-60 points	61-75 points	>75 points
Soil BTEX	0.006 ppm Benzene 4 ppm Toluene 6 ppm Ethylbenzene 28 ppm Total Xylenes	0.17 ppm Benzene 7 ppm Toluene 10 ppm Ethylbenzene 47 ppm Total Xylenes	0.335 ppm Benzene 9 ppm Toluene 14 ppm Ethylbenzene 67 ppm Total Xylenes	0.5 ppm Benzene 12 ppm Toluene 18 ppm Ethylbenzene 85 ppm Total Xylenes
Groundwater BTEX	0.005 ppm Benzene 1 ppm Toluene 0.7 ppm Ethylbenzene 10 ppm Total Xylenes	0.005 ppm Benzene 1 ppm Toluene 0.7 ppm Ethylbenzene 10 ppm Total Xylenes	0.005 ppm Benzene 1 ppm Toluene 0.7 ppm Ethylbenzene 10 ppm Total Xylenes	0.005 ppm Benzene 1 ppm Toluene 0.7 ppm Ethylbenzene 10 ppm Total Xylenes
Soil TPH (gasoline)	105 ppm TPH	300 ppm TPH	450 ppm TPH	600 ppm TPH
Soil TPH (others)	380 ppm TPH	642 ppm TPH	904 ppm TPH	1156 ppm TPH

5.3 Summary of Risks

The RBSLs in this demonstration were conservatively calculated using one-half the detection limit to represent nondetects. The resulting RBSLs, however, were consistently higher than criteria set by the state of Ohio for emergency response to TPH spills. The leaching to groundwater pathway for the residential scenario yielded the lowest RBSLs (from sample IW20S30-005, the sample of lowest concentration of the six analyzed for fractionation). Higher RBSL were obtained for the residential scenario direct contact pathway. The average RBSL for the commercial scenario leaching pathway was approximately five times higher than that of the residential scenario. RBSLs are averaged by first calculating a TPH mixture RBSL for each sample and then averaging the RBSLs. The commercial direct contact RBSLs were also higher than the residential counterparts. The average TPH concentration did not exceed the average RBSL for both pathways. Indoor and outdoor air pathways were not evaluated.

6.0 CONCLUSIONS

Although this site was not planned as a demonstration site, this exercise indicated that the Working Group protocol provides scientifically defensible cleanup criteria for a fresh release site. The fractions are easily implemented within the RBCA framework. The residential and commercial RBSLs developed using the Working Group protocol were approximately 4 and 11 times higher, respectively, than those determined using the Category 3 levels indicated by the Ohio EPA Guidance for Emergency Response. The RBSLs developed for this site were especially suitable due to the lack of carcinogenic BTEX or PAH detected.

Presently few laboratories perform the fractionation method. The turn around time for data is typically much longer than that for conventional TPH analyses. This delay may impede it's usefulness for assessing and developing emergency response criteria in situations such as this site. However, the Working Group approach is appropriate for surface releases, which tend to be readily weathered due to high exposure to the elements. If leaching from surface soils is a complete exposure pathway, the Working Group protocol is more appropriate than conventional methods to identify actual constituents that may leach. Initial costs of characterizing a clean-up activity may be higher due to the need for additional and more costly analyses. However, remediation costs may be significantly reduced because clean-up levels may be much higher when they are risk based verses non-risk based. The Working Group approach also provides a much better understanding of the remaining constituents in a complex weathered mixture.

The range of TPH results from both the Direct Method and the conventional method were within an order of magnitude; however, because samples analyzed by the two methods were not duplicates, a meaningful comparison could not be made. In future demonstrations, duplicate samples will be analyzed by the same lab using the different analytical methods.

7.0 REFERENCES

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HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 97309-0006A

Laboratory ID: 2813057
Sample ID: 25008

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	4.00	ND	4.00	ND	NA
VRH 2 **	NA	NA	14.71	4.00	ND	4.00	14.89	NA
>C8 - <=C10	144.6	8	89.6	8	8.1	8	97.7	68%
>C10 - <=C12	696.0	8	447.4	8	59.4	8	506.8	73%
>C12 - <=C16	505	20	328	20	76	20	403	80%
>C16 - <=C21	ND	20	ND	20	ND	20	22	NA
>C21 - <=C35	ND	50	ND	50	ND	50	53	NA
Total >C8 - <=C35	1379	100	920	100	162	100	1082	78%
Total >C5 - <=C35	NA	NA	935	100	162	100	1097	NA

Laboratory ID: 2813057 **C5 to C35 Hydrocarbons "Dry Weight Data"** % moisture = 20.8
Sample ID: 25008

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	5.05	ND	5.05	ND	NA
VRH 2 **	NA	NA	18.57	5.05	ND	5.05	18.80	NA
>C8 - <=C10	182.6	10	113.2	10	10.2	10	123.3	68%
>C10 - <=C12	878.7	10	564.9	10	75.0	10	639.9	73%
>C12 - <=C16	638	25	414	25	96	25	509	80%
>C16 - <=C21	ND	25	ND	25	ND	25	27	NA
>C21 - <=C35	ND	63	ND	63	ND	63	66	NA
Total >C8 - <=C35	1741	126	1162	126	204	126	1366	78%
Total >C5 - <=C35	NA	NA	1181	126	204	126	1385	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 2813058
Sample ID: 25099

Extractable Batch ID: 97309-0006A

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8.00	ND	0.20	0.42	NA
VRH 2 **	NA	NA	54.72	8.00	0.87	0.20	55.60	NA
>C8 - <=C10	995.8	8	638.0	8	50.5	8	688.5	69%
>C10 - <=C12	3145.0	8	2250.2	8	273.6	8	2523.8	80%
>C12 - <=C16	1870	20	1314	20	297	20	1610	86%
>C16 - <=C21	74	20	54	20	ND	20	71	96%
>C21 - <=C35	96	50	79	50	ND	50	83	86%
Total >C8 - <=C35	6181	100	4336	100	641	100	4976	81%
Total >C5 - <=C35	NA	NA	4391	100	642	100	5032	NA

Laboratory ID: 2813058 **C5 to C35 Hydrocarbons "Dry Weight Data"** % moisture = 16.2
Sample ID: 25099

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	9.55	ND	0.24	0.51	NA
VRH 2 **	NA	NA	65.30	9.55	1.04	0.24	66.34	NA
>C8 - <=C10	1188.3	10	761.3	10	60.3	10	821.6	69%
>C10 - <=C12	3753.0	10	2685.2	10	326.5	10	3011.7	80%
>C12 - <=C16	2231	24	1567	24	354	24	1922	86%
>C16 - <=C21	88	24	65	24	ND	24	84	96%
>C21 - <=C35	115	60	95	60	ND	60	99	86%
Total >C8 - <=C35	7376	119	5174	119	765	119	5938	81%
Total >C5 - <=C35	NA	NA	5239	119	766	119	6005	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 97309-0006A

Laboratory ID: 2813059
Sample ID: 5021

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8.00	ND	8.00	ND	NA
VRH 2 **	NA	NA	133.55	8.00	ND	8.00	136.48	NA
>C8 - <=C10	604.8	40	459.0	8	35.7	8	494.7	82%
>C10 - <=C12	2223.6	40	1628.3	8	198.7	8	1827.0	82%
>C12 - <=C16	1438	100	1015	20	216	20	1231	86%
>C16 - <=C21	ND	100	41	20	ND	20	53	NA
>C21 - <=C35	ND	250	71	50	ND	50	74	NA
Total >C8 - <=C35	4395	500	3215	100	464	100	3679	84%
Total >C5 - <=C35	NA	NA	3349	120	467	120	3816	NA

Laboratory ID: 2813059 **C5 to C35 Hydrocarbons "Dry Weight Data"** % moisture = 18.9
Sample ID: 5021

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	9.86	ND	9.86	ND	NA
VRH 2 **	NA	NA	164.67	9.86	ND	9.86	168.29	NA
>C8 - <=C10	745.7	49	566.0	10	44.0	10	610.0	82%
>C10 - <=C12	2741.8	49	2007.8	10	245.0	10	2252.8	82%
>C12 - <=C16	1773	123	1251	25	266	25	1517	86%
>C16 - <=C21	ND	123	51	25	ND	25	65	NA
>C21 - <=C35	ND	308	88	62	ND	62	91	NA
Total >C8 - <=C35	5419	617	3964	123	572	123	4536	84%
Total >C5 - <=C35	NA	NA	4130	148	576	148	4706	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 2813060 Extractable Batch ID: 97309-0006A
Sample ID: 5052

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	20.00	ND	20.00	ND	NA
VRH 2 **	NA	NA	122.90	20.00	ND	20.00	125.42	NA
>C8 - <=C10	1725.4	40	1290.8	80	89.0	8	1379.8	80%
>C10 - <=C12	5755.1	40	4269.1	80	531.9	8	4801.0	83%
>C12 - <=C16	3415	100	2361	200	566	20	2926	86%
>C16 - <=C21	189	100	ND	200	29	20	225	119%
>C21 - <=C35	322	250	ND	500	ND	50	321	100%
Total >C8 - <=C35	11406	500	8434	1000	1219	100	9653	85%
Total >C5 - <=C35	NA	NA	8558	1000	1221	100	9779	NA

Laboratory ID: 2813060 **C5 to C35 Hydrocarbons "Dry Weight Data"** **% moisture = 17.1**
Sample ID: 5052

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	24.13	ND	24.13	ND	NA
VRH 2 **	NA	NA	148.25	24.13	ND	24.13	151.29	NA
>C8 - <=C10	2081.3	48	1557.1	97	107.4	10	1664.4	80%
>C10 - <=C12	6942.2	48	5149.7	97	641.6	10	5791.3	83%
>C12 - <=C16	4119	121	2848	241	682	24	3530	86%
>C16 - <=C21	228	121	ND	241	35	24	271	119%
>C21 - <=C35	388	302	ND	603	ND	60	388	100%
Total >C8 - <=C35	13758	603	10174	1206	1470	121	11644	85%
Total >C5 - <=C35	NA	NA	10323	1206	1473	121	11797	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 97309-0006A

Laboratory ID: 2813061
Sample ID: 20013

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8.00	ND	8.00	ND	NA
VRH 2 **	NA	NA	42.16	8.00	ND	8.00	42.77	NA
>C8 - <=C10	993.7	40	833.1	80	57.7	8	890.8	90%
>C10 - <=C12	4107.4	40	3228.0	80	375.6	8	3603.6	88%
>C12 - <=C16	2632	100	1854	200	439	20	2293	87%
>C16 - <=C21	122	100	ND	200	34	20	106	86%
>C21 - <=C35	ND	250	ND	500	ND	50	399	NA
Total >C8 - <=C35	8073	500	6379	1000	913	100	7292	90%
Total >C5 - <=C35	NA	NA	6421	1000	914	100	7335	NA

Laboratory ID: 2813061 **C5 to C35 Hydrocarbons "Dry Weight Data"** % moisture = 17.2
Sample ID: 20013

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	9.66	ND	9.66	ND	NA
VRH 2 **	NA	NA	50.92	9.66	ND	9.66	51.65	NA
>C8 - <=C10	1200.2	48	1006.2	97	69.7	10	1075.8	90%
>C10 - <=C12	4960.7	48	3898.6	97	453.7	10	4352.2	88%
>C12 - <=C16	3179	121	2239	242	531	24	2770	87%
>C16 - <=C21	147	121	ND	242	41	24	127	86%
>C21 - <=C35	ND	302	ND	604	ND	60	481	NA
Total >C8 - <=C35	9750	604	7704	1208	1103	121	8807	90%
Total >C5 - <=C35	NA	NA	7755	1208	1103	121	8859	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 2813062 Extractable Batch ID: 97309-0006A
Sample ID: 30005

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	2.00	ND	2.00	ND	NA
VRH 2 **	NA	NA	ND	2.00	ND	2.00	ND	NA
>C8 - <=C10	29.7	8	17.6	8	ND	8	19.8	67%
>C10 - <=C12	166.2	8	96.9	8	16.9	8	113.8	68%
>C12 - <=C16	158	20	88	20	26	20	114	72%
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	375	100	216	100	ND	100	273	73%
Total >C5 - <=C35	NA	NA	218	100	ND	100	274	NA

Laboratory ID: 2813062 **C5 to C35 Hydrocarbons "Dry Weight Data"** % moisture = 16.9
Sample ID: 30005

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	2.41	ND	2.41	ND	NA
VRH 2 **	NA	NA	ND	2.41	ND	2.41	ND	NA
>C8 - <=C10	35.7	10	21.2	10	ND	10	23.9	67%
>C10 - <=C12	200.0	10	116.6	10	20.3	10	136.9	68%
>C12 - <=C16	190	24	106	24	32	24	138	72%
>C16 - <=C21	ND	24	ND	24	ND	24	ND	NA
>C21 - <=C35	ND	60	ND	60	ND	60	ND	NA
Total >C8 - <=C35	451	120	260	120	ND	120	328	73%
Total >C5 - <=C35	NA	NA	262	120	ND	120	330	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

Quality Control Analyses (MS/MSD) for Hydrocarbon Speciation
C8 to C35 Hydrocarbons by Pentane Extraction "As Received (Wet Weight) Data"

Laboratory ID: 2813057
Sample ID: 25008

Batch ID: 97309-0006A

Specific Aliphatic Compounds in Aliphatic Fraction

Analyte	Approximate Carbon Number Range	Background (mg/kg)	LOQ	MS (mg/kg)	MS Result (mg/kg)	Recovery (%)	MSD result (mg/kg)	Recovery (%)	RPD (%)
n-Octane	C8	1.4	1	25.0	18.1	67.0%	18.4	68.2%	1.6%
n-Decane	>C8 - <=C10	18.2	1	25.0	36.3	72.4%	29.8	46.5%	19.6%
n-Dodecane	>C10 - <=C12	43.6	1	25.0	71.3	111.0%	54.5	43.6%	26.8%
n-Hexidecane	>C12 - <=C16	2.8	1	2.5	6.4	145.2%	5.6	113.2%	13.3%
n-Eicosane	>C16 - <=C21	ND	1	25.0	18.8	75.3%	20.2	80.6%	6.8%
n-Docosane	>C21 - <=C35	0.2	1	25.0	18.8	74.5%	18.0	71.3%	4.4%
n-Dotriacontane	>C21 - <=C35	ND	1	25.0	22.2	88.6%	19.8	79.0%	11.5%

Specific Aromatic Compounds in Aromatic Fraction

Analyte	Approximate Carbon Number Range	Background (mg/kg)	LOQ	MS (mg/kg)	MS Result (mg/kg)	Recovery (%)	MSD result (mg/kg)	Recovery (%)	RPD (%)
Ethylbenzene	>C8 - <=C10	ND	1	25.0	20.8	83.2%	21.8	87%	4.6%
1,3,5,-Trimethylbenzene	>C8 - <=C10	ND	1	25.0	21.6	86.2%	22.3	89%	3.2%
Naphthalene	>C10 - <=C12	ND	1	25.0	28.1	112.4%	19.7	79%	35.2%
Acenaphthene	>C12 - <=C16	5.4	1	25.0	22.3	67.7%	21.7	65%	2.7%
Anthracene	>C16 - <=C21	ND	1	25.0	13.8	55.0%	14.4	57%	4.3%
Chrysene	>C21 - <=C35	ND	1	25.0	16.0	63.9%	17.5	70%	9.1%

Note: the spiking concentration for n-hexadecane was 10x lower than our prefered target value.

Prepared by Delwyn K. Schumacher

HYDROCARBON SPECIATION PROJECT

Quality Control Analyses (Blank/LCS) for Hydrocarbon Speciation
C8 to C35 Hydrocarbons by Pentane Extraction

Batch ID: 97309-0006A

Aliphatic Fraction

Approximate Carbon Number Range	Blank (mg/kg)	LOQ (mg/kg)	Amount Spiked (mg/kg)	LCS Result (mg/kg)	% LCS Recovery
>C8 - <=C10	0.6	4	25.0	17.8	68.8%
>C10 - <=C12	0.6	8	25.0	17.0	65.5%
>C12 - <=C16	0.3	20	2.5	3.7	136.2%
>C16 - <=C21	1.2	20	25.0	21.5	81.0%
>C21 - <=C35	6.3	50	50.0	35.1	57.6%
Total	9.0	100	128	95	67.5%

Specific Aliphatic Compounds in Aliphatic Fraction

Analyte	Blank (mg/kg)	LOQ (mg/kg)	Amount Spiked (mg/kg)	LCS Result (mg/kg)	% LCS Recovery
n-Octane	ND	1	25.0	15.6	62.3%
n-Decane	ND	1	25.0	16.7	66.8%
n-Dodecane	ND	1	25.0	17.4	69.4%
n-Hexidecane	ND	1	2.5	2.5	100.8%
n-Eicosane	ND	1	25.0	17.3	69.0%
n-Docosane	ND	1	25.0	15.9	63.4%
n-Dotriacontane	ND	1	25.0	14.1	56.4%

Aromatic Fraction

Approximate Carbon Number Range	Blank (mg/kg)	LOQ (mg/kg)	Amount Spiked (mg/kg)	LCS Result (mg/kg)	% LCS Recovery
>C8 - <=C10	0.5	8	50.0	38.3	75.7%
>C10 - <=C12	0.7	8	25.0	19.9	76.8%
>C12 - <=C16	0.6	20	25.0	21.6	84.1%
>C16 - <=C21	0.8	20	25.0	19.0	72.6%
>C21 - <=C35	5.4	50	25.0	22.3	67.5%
Total	8.0	100	150	121	75.4%

Specific Aromatic Compounds in Aromatic Fraction

Analyte	Blank (mg/kg)	LOQ (mg/kg)	Amount Spiked (mg/kg)	LCS Result (mg/kg)	% LCS Recovery
Ethylbenzene	ND	1	25.0	19.4	77.6%
1,3,5,-Trimethylbenzene	ND	1	25.0	19.2	77.0%
Naphthalene	ND	1	25.0	16.5	66.2%
Acenaphthene	ND	1	25.0	15.1	60.5%
Anthracene	ND	1	25.0	13.0	52.0%
Chrysene	ND	1	25.0	15.7	62.9%

Note: The spiking concentration for n-hexadecane was 10x lower than our prefered target value

APPENDIX B RBSL CALCULATION PROCEDURES

The procedure for calculating a TPH RBSL for cross-media pathways based upon summing the risk from each fraction is complex. Please note that the following procedure is only appropriate for calculation of RBSLs for cross-media pathways since it sets as an upper limit for the RBSL the degree of saturation, which does not limit exposure for direct routes such as soil ingestion, dermal exposure and inhalation of particulates. An additional procedure used to calculate exposure for direct pathways is provided later.

Cross-media Pathways

Partitioning qualities govern how a chemical interacts with its environment. Specific physical properties responsible include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. A brief discussion of the role these parameters play in basic partitioning in the environment is provided in the following paragraphs. The fraction-specific values for each of the described fate and transport parameters is provided in Table 3-1. The equations used to develop these fate and transport properties is available in the Working Group's Volume 3 "Selection of Representative TPH Fractions Based on Fate and Transport Considerations" (TPHCWG, 1998a).

The solubility of aromatic hydrocarbons, for any EC number, is generally greater than that of aliphatic hydrocarbons, especially at high EC values. The variability in solubility around any given EC value is about an order of magnitude. The higher solubility of the aromatics means that aromatic hydrocarbons are more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons.

The soil-water sorption coefficient (k_s) expresses the tendency of a chemical to be adsorbed onto a soil particle. The magnitude of the sorption coefficient for most soil/water systems is a function of the hydrophobicity of the chemical (as indicated by its solubility) and the organic carbon content of the soil. For non-ionic, hydrophobic chemicals such as petroleum hydrocarbons, the primary property found to control sorption is the organic carbon content (f_{oc}) of the soil.

In general, aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fraction of an equivalent EC. This tendency was previously indicated by the low solubility observed for aliphatic fractions. The majority of log k_{oc} (carbon-water sorption coefficient) values presented in Table 3-1 were derived from the octanol-water partitioning coefficient.

There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related. This relationship is expected because both EC and vapor pressure are largely functions of a compound's boiling point.

The Henry's law constant (H_c) is definable as an air-water partitioning coefficient and may be measured as the ratio of a compound's concentration in air to its concentration in water at equilibrium. Aliphatics and aromatics behave differently based on Henry's law constant. For aromatic fractions, the Henry's law constant decreases with increasing EC; for aliphatic fractions, the Henry's law constant is virtually unaffected by EC. In general, aliphatic hydrocarbons are less soluble and more volatile than aromatic hydrocarbons. It is important to note, however, that benzene, an aromatic compound, is very volatile and more toxic than the corresponding aliphatic fractions. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The parameters described above are combined into simple fate and transport models to evaluate the partitioning and migration of chemicals for the different applicable pathways. For leaching and volatilization pathways where transport and therefore exposure are maximized at the saturation concentration for specific fractions, the following equation is solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = Min\left(\sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i}, \sum_{i=1}^{i=n} \frac{C_{isat}}{RBSL_i} \right) \leq 1 \quad \text{given that}$$

$$\sum_{i=l}^{i=13} f_i = \sum_{i=l}^{i=n} \frac{C_i}{C_{TPH}} = 1$$

where:

HI	=	Hazard Index (typically ≤ 1) [unitless]
n	=	number of fractions (13 total) [unitless]
HQ	=	Hazard Quotient for each specific fraction [unitless]
f_i	=	Percent Weight of each TPH fraction in total TPH mixture [unitless]
C_{TPH}	=	Concentration of whole TPH mixture [mg/kg]
$RBSL_i$	=	Tier 1 risk-based screening level for i^{th} TPH fraction [mg/kg]
$C_{i\ sat}$	=	Saturation concentration for i^{th} TPH fraction [mg/kg]

The saturation concentration is defined by the following equation:

$$C_{sat}\left[{}^{mg}/_{kg}\right] = \frac{S}{\rho_s} * [H_c \theta_{as} + \theta_{ws} + k_s \rho_s]$$

where:

S	=	Fraction effective solubility [mg/L]
ρ_s	=	Soil Bulk Density [g/cm^3]
H_c	=	Henry's Constant [atm-m^3/mol]
θ_{as}	=	Volumetric air content of the soil [cm^3/cm^3]
θ_{ws}	=	Volumetric water content of the soil [cm^3/cm^3]
k_s	=	Soil sorption coefficient (k_{oc}*f_{oc}) [cm^3/g]

Note: The effective solubility of a hydrocarbon fraction is equal to the fraction's solubility limit multiplied by the mole fraction of the hydrocarbon fraction in the mixture (i.e., TPH).

The value obtained for C_{sat} will vary considerably if the effective C_{sat} of each fraction present in the sample is considered through the use of Raoult's law. The two equations above are iteratively solved for each TPH fraction, which is the additive mixture RBSL for the soil sample. Residual saturation is the point at which any increase in chemical concentration will not change the risk, up until the point at which free product migration becomes an issue. For purposes of comparing RBSLs obtained using different analytical fractionation methods, such as the

Massachusetts Department of Environmental Protection TPH Method, Raoult's law was not used to calculate the RBSLs presented in the following sections.

Soil Leaching to Groundwater Pathway

Leaching of contaminants from impacted soil into groundwater through infiltrating water is one exposure pathway evaluated in the RBCA analysis. Soil RBSLs are calculated to be protective of groundwater quality. This involves: 1) calculating a groundwater RBSL ($RBSL_{gw}$) to determine an acceptable water concentration, 2) calculating a leachate concentration protective of groundwater (based on the groundwater RBSL) and 3) calculating a soil concentration which would result in this leachate concentration. The following equation calculates the $RBSL_{gw}$ for ingestion.

$$RBSL_{gw}\left[\frac{mg}{L-water}\right]=\frac{THQ \times RfD_o \times BW \times AT_n \times 365\,{}^{days}\!/_{yr}}{IR_{water} \times EF \times ED}$$

where:

THQ	=	Target hazard quotient [unitless]
RfD_o	=	Oral chronic reference dose [mg/kg-day]
BW	=	Body weight [kg]
AT_n	=	Averaging time for noncarcinogens [yr]
IR_{water}	=	Daily ingestion rate [L/day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [yr]

The $RBSL_{gw}$ is based on a target hazard quotient of 1.0. Exposure parameters are provided in Table B-1. RfDs for the fractions are listed in Table 3-2.

TABLE B-1 TIER 1 DEFAULT EXPOSURE FACTORS

Name	Parameter	Units	Residential Scenario	Commercial Scenario
Averaging Time: carcinogens	AT_c	yr	70	70
Averaging Time: non-carcinogens	AT_n	yr	30	25
Body Weight	BW	kg	70	70
Exposure Duration	ED	yr	30	25
Exposure Frequency	EF	days/yr	250	250
Ingestion rate: soil	IR_{soil}	mg/day	100	50
Inhalation Rate: air-indoor	$IR_{air\text{-}in}$	m^3/day	NA	20
Inhalation Rate: air-outdoor	$IR_{air\text{-}out}$	m^3/day	20	20
Ingestion rate: water	IR_w	L/day	1	1
Soil Adherence Factor	M	mg/cm^2	0.5	0.5
Dermal Absorption Factor	RAF_d	--	c.s.	c.s.
Oral Absorption Factor	RAF_o	--	1	1
Skin surface area	SA	cm^2/day	3160	3160
Target Hazard Quotient for Individual Constituents.	THQ	--	1	1
Target Excess Individual Lifetime Cancer Risk	TR	--	1E-06	1E-06

Note: NA = not applicable

The analytical model used to estimate soil leaching to groundwater determines the partitioning of a constituent into water, vapor and sorbed phases based on the physical and chemical properties of the constituent. In this model, infiltrating water migrates through contaminated soils in the vadose zone. At this point, some of the contaminant partitions from the soil or vapor phase into the water phase. This leachate is then assumed to migrate completely and instantaneously into groundwater. Some dilution of the leachate is included using an attenuation factor based on infiltration rate, groundwater velocity, source width and height of the mixing zone in the water column. The equation describing this attenuation factor (AF) is as follows:

$$AF = \left[1 + \frac{U_{GW}\delta_{GW}}{IW}\right]$$

where:

U_{GW} = Groundwater velocity [ft/day]

δ_{GW} = Height of groundwater mixing zone [ft]

I = Precipitation infiltration rate [ft/day]

W = Width of the source area parallel to the mixing zone [ft]

Partitioning into the three phases, soil, water and air, is governed by the partitioning factor. As Henry's law constant is applicable only to dilute solutions, the use of this model is not appropriate when free phase liquid is present. The partitioning factor (PF) is defined as:

$$PF = \frac{[\theta_{ws} + k_s\rho_s + H_c\theta_{as}]}{\rho_s}$$

where:

θ_{ws}	=	Soil volumetric water content [cm^3/cm^3]
k_s	=	Soil sorption coefficient (k_{oc}*f_{oc}) [cm^3/g]
ρ_s	=	Soil density [g/cm^3]
H_c	=	Henry's Constant [atm-m^3/mol]
θ_{as}	=	Soil volumetric air content [cm^3/cm^3]

The PF multiplied by AF, which accounts for dilution of leached water into underlying groundwater, is termed the leaching factor (LF). The ultra-conservative leaching model assumes that no attenuation of leachate occurs from the vadose to the saturated zone. In fact, biological degradation of the constituent or repartitioning onto soil or into the vapor phase are all likely to occur as the leachate migrates to groundwater. Other assumptions of the model include: 1) a constant chemical concentration in the subsurface soils, 2) linear equilibrium partitioning within the soil matrix between sorbed, dissolved and vapor phases, 3) steady-state leaching from the vadose zone to groundwater and 4) steady state, well-mixed dispersion of the leachate within the groundwater mixing zone. Therefore the LF, which governs the movement of contaminants from soil to infiltrating water, incorporates both the PF and the AF, in the following equation:

$$LF = \frac{\rho_s}{[\theta_{ws} + k_s + H\theta_{as}]\left(1 + \frac{U_{gw}\delta_{gw}}{IW}\right)}$$

where:

LF	=	leaching factor [mg/L-H_2O / mg/kg-soil]
U_{gw}	=	groundwater Darcy velocity [cm/yr]
δ_{gw}	=	groundwater mixing zone thickness [cm]
I	=	infiltration rate of water through soil [cm/yr]
W	=	width of source area parallel to groundwater flow direction [cm]

Parameters for the leaching pathway are provided in Table B-2. Once the LF has been established, fraction-specific soil RBSLs may be calculated as follows:

$$RBSL_s\left[\frac{mg}{kg-soil}\right] = \frac{RBSL_w\left[\frac{mg}{L-air}\right]}{LF_{sw}}$$

The fraction-specific RBSLs are then used to calculate "whole TPH" RBSLs.

Volatilization to Indoor Air Pathway

The mathematical model used to estimate volatilization from soil to indoor air is based upon the partitioning of a constituent into water, vapor and sorbed phases as determined by the physical properties of the chemical. The model accounts for the contaminant partitioning into soil pore gas and migrating through the vadose zone to the base of a building foundation. From there the gas diffuses through cracks in the foundation and into the building air space, where exposure through inhalation may occur.

The first step in calculating a soil RBSL for the indoor air pathway requires the calculation of an air concentration or RBSL, which is protective of indoor air quality (based on a target HQ of 1.0). Indoor air RBSLs are calculated for each TPH fraction and then a "whole TPH" RBSL is calculated based on the percent composition of each fraction. The following equation is used to calculate the air RBSLs:

$$RBSL_{air}\left[\frac{\mu g}{m^3\,air}\right] = \frac{THQ \times RfD_i \times BW \times AT_n \times 365\,{}^{days}\!/_{yr} \times 10^3\,{}^{\mu g}\!/_{mg}}{IF_{air-in} \times EF \times ED}$$

where:

THQ	=	Target hazard quotient [unitless]
RfD_i	=	Inhalation chronic reference dose [mg/kg-day]
BW	=	Body weight [kg]
AT_n	=	Averaging time for noncarcinogens [yr]
IF_{air-in}	=	Daily inhalation rate [m^3/day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [years]

The second step in calculating a soil concentration ($RBSL_{soil}$) which will result in an acceptable indoor air concentration ($RBSL_{air}$) is to model the transport of contaminants from the vadose soil to indoor air. This model is extremely conservative, assuming: 1) a constant chemical concentration in subsurface soils; 2) linear equilibrium partitioning in the soil between sorbed, dissolved and vapor phases; and 3) steady-state vapor- and liquid-phase diffusion through the vadose zone and foundation cracks. In addition, the model assumes that vapors migrate completely and instantaneously into the building, i.e., no attentuation occurs. It does not account for any biodegradation and soil sorption which could occur as the vapor migrates through the vadose zone.

TABLE B-2 PARAMETERS FOR CROSS-MEDIA RBSL CALCULATIONS

Description	Parameter	Units	Tier 1 Default Values
Ambient air mixing zone height	δ_{air}	cm	200
Areal fraction of cracks in foundations/walls	η	cm^2/cm^2	0.01
Averaging time for vapor flux	τ	s	7.88E+08
Carbon-water sorption coefficient	k_{oc}	cm^3/g	c.s.
Depth to groundwater (hcap+hv)	L_{GW}	cm	300
Depth to subsurface soil sources	L_S	cm	100
Diffusion coefficient in air	D^{air}	cm^2/s	c.s.
Diffusion coefficient in water	D^{wat}	cm^2/s	c.s.
Enclosed space air exchange rate	ER	1/s	0.00023
Enclosed space foundation or wall thickness	L_{crack}	cm	15
Enclosed space volume/infiltration area ratio	L_B	cm	300 -commercial
Fraction organic carbon in soil	f_{oc}	g/g	0.01
Groundwater Darcy velocity	μ_{gw}	cm/yr	2500
Groundwater mixing zone thickness	δ_{gw}	cm	200
Henry's Law Constant	H	(cm^3/cm^3)	c.s.
Infiltration rate of water through soil	I	cm/yr	30
Lower depth of surficial soil zone	d	cm	100
Particulate emission rate	PE	g/cm^2-s	2.2E-10
Particulate Emission Rate	VF_p	$(mg/m^3)/(mg/kg)$	6.90E-14
Pure component solubility in water	S	mg/L	c.s.
Soil bulk density	ρ	g/cm^3	1.7
Soil-water sorption coefficient	k_s	cm^3/g	$f_{oc}*k_{oc}$
Thickness of capillary fringe	h_{cap}	cm	5
Thickness of vadose zone	h_v	cm	295
Total soil porosity	θ_T	cm^3/cm^3	0.38
Volatilization Factor	VF_i	$\frac{(mg/m^3)}{(mg/m^3)}$	c.s. & media specific
Volumetic air content in vadose zone soils	θ_{as}	cm^3/cm^3	0.26
Volumetric air content in capillary fringe soils	θ_{acap}	cm^3/cm^3	0.038
Volumetric air content in foundation cracks	θ_{acrack}	cm^3/cm^3	0.26
Volumetric water content vadose zone soils	θ_{ws}	cm^3/cm^3	0.12
Volumetric water content: capillary fringe	θ_{wcap}	cm^3/cm^3	0.342
Volumetric water content: foundation cracks	θ_{wcrack}	cm^3/cm^3	0.12
Width of source area parallel to flow direction	W	cm	1500
Wind speed above ground surface	U_{air}	cm/s	225

Dilution of vapor is expected to occur between the source and the building. Therefore the following diffusion factor is used:

$$D_s^{eff}\left[\frac{cm^2}{s}\right] = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{Hc}\times\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

where:

D^{air}	=	Diffusion coefficient in air [cm^2/sec]
θ_{as}	=	Soil volumetric air content [cm^3-air/cm^3-soil]
θ_T	=	Total soil porosity [cm^3/cm^3]
D^{wat}	=	Diffusion coefficient in water [cm^2/sec]
H_c	=	Henry's constant [cm^3-air/cm^3-soil]
θ_{ws}	=	Soil volumetric water content [cm^3-water/cm^3-soil]

The diffusion of the pore gas through cracks in the foundation is governed by the following equation:

$$D_{crack}^{eff}\left[\frac{cm^2}{s}\right] = D^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{Hc}\times\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$$

where:

D^{air}	=	Diffusion coefficient in air [cm^2/sec]
θ_{acrack}	=	Volumetric air content in foundation [cm^3-air/cm^3]
θ_T	=	Total soil porosity [cm^3/cm^3]
D^{wat}	=	Diffusion coefficient in water [cm^2/sec]
H_c	=	Henry's constant [cm^3-air/cm^3-soil]
θ_{wcrack}	=	Volumetric water content in foundation [cm^3-water/cm^3]

The default parameters used in these equations are provided in Table B-2.

Chemical Partitioning

The partitioning equation which accounts for the movement of chemicals from the soil into the vapor phase in the soil pore space is defined as the partitioning factor (soil/vapor phase) as follows:

$$PF_{S-V} = \frac{Hc\rho_s}{\theta_{ws} + k_s\rho_s + Hc\,\theta_{as}}$$

where:

PF_{S-V}	=	Soil/Vapor phase partitioning factor [unitless]
H_c	=	Henry's Constant [cm^3-water/cm^3-air]
ρ_s	=	Soil bulk density [g/cm^3]
θ_{ws}	=	Soil volumetric water content [cm^3/cm^3]
k_s	=	Soil sorption coefficient (k_{oc}*f_{oc}) [cm^3/g]
θ_{as}	=	Soil volumetric air content [cm^3/cm^3]

The diffusion coefficients and partitioning factor are combined to yield a subsurface soil to enclosed space volatilization factor (VF_{sesp}), which takes into account partitioning, diffusion in the vadose zone, effective diffusion into an enclosed space and adds terms for accumulation of vapors in the enclosed space. The VF is calculated as follows:

$$VF_{sesp} = \frac{\dfrac{(PF_{S-V})D_s^{eff}}{L_s(ER)L_B}}{1+\dfrac{D_s^{eff}}{ER\,L_s}+\dfrac{D_s^{eff}+L_{crack}}{(L_s D_{crack}^{eff})\times\eta}} \times 10^3 \left[\frac{cm^3-kg}{m^3-g}\right]$$

where:

PF_{s-v}	=	Soil/Vapor phase partitioning factor [unitless]
D_s^{eff}	=	Effective diffusion coefficient in soil [cm^2/s]
L_s	=	Depth to subsurface soil sources [cm]
ER	=	Enclosed-space air exchange rate [s^{-1}]
L_B	=	Enclosed-space volume/infiltration area ratio [cm]
L_{crack}	=	Enclosed-space foundation or wall thickness [cm]
D_{crack}^{eff}	=	Effective diffusion coefficient through foundation cracks [cm^2/s]
η	=	Areal fraction of cracks in foundation/walls [cm^2/cm^2]

Values in these calculations are provided in Table B-2. The term VF_{sesp}, when combined with the allowable concentration of contaminant in the air space ($RBSL_{air}$), determines the maximum allowable concentration in the subsurface soil source area as shown in the following equation:

$$RBSL_{svin}\left[\frac{mg}{kg-soil}\right] = \frac{RBSL_{air}\left[\frac{mg}{m^e-air}\right]}{VF_{sesp}}$$

where:

$RBSL_{svin}$	=	RBSL (volatilization to indoor air pathway) [mg/kg]

Fraction-specific RBSLs are then used to calculate the "whole TPH" RBSLs.

Volatilization to Outdoor Air Pathway

The volatilization to outdoor air model is similar to the indoor air model. It assumes contaminants partition into soil pore gas which migrates through the vadose zone to the surface and mixes with the ambient air. Dispersion into ambient air is modeled using a "box model", which is typically valid for source widths of less than 100 feet parallel to wind direction. Steady-state well-mixed atmospheric dispersion of the vapors within the breathing zone is assumed. Other assumptions listed for the indoor air model include linear equilibrium partitioning, steady-state vapor diffusion through the vadose zone and no attenuation of the chemical as it migrates through the vadose zone.

The calculation of a soil RBSL protective of outdoor air quality is similar to that used for the indoor air pathway. A volatilization factor for ambient air (VF_{samb}) is derived, using the same effective diffusion coefficient in vadose soils and partitioning factor. Default values are provided in Table B-2.

$$VF_{samb}\left[\frac{mg/m^3-air}{mg/kg-soil}\right]=\frac{PF_{S-V}}{1+\frac{U_{air}\delta_{air}Ls}{D_S^{eff}\,w}}\times 10^3\left[\frac{cm^3-kg}{m^3-g}\right]$$

where:

PF_{s-v}	=	Soil/Vapor phase partitioning factor [unitless]
U_{air}	=	Wind speed above ground surface in ambient mixing zone [cm/s]
δ_{air}	=	Ambient air mixing zone height [cm]
D_s^{eff}	=	Effective diffusion coefficient in soil [cm^2/s]
w	=	Width of source area parallel to wind direction [cm]

VF_{samb} is then combined with the allowable concentration of contaminant in the air space ($RBSL_{air}$) to determine the maximum allowable concentration of contaminant in the subsurface soil ($RBSL_{svout}$), as shown below:

$$RBSL_{svout}=\frac{RBSL_{air}\left[\frac{mg}{m^e-air}\right]}{VF_{samb}}$$

Fraction-specific RBSLs are then used to calculate "whole TPH" RBSLs. Parameter values are presented in Table B-2.

Direct Contact Pathway

For direct exposure routes such as soil ingestion, dermal absorption and inhalation of particulates, exposure is not limited by C_{sat}. The assumption is made that intake will continue to increase linearly with soil loading beyond C_{sat} for ingestion, dermal and particulate inhalation pathways. For the direct contact pathways, the following equation is solved:

$$HI=\sum_{i=1}^{i=n}HQ_i=\sum_{i=1}^{i=n}\frac{f_iC_{TPH}}{RBSL_i}\le 1$$

$$RBSL_{ss}\left[\frac{ug}{kg-soil}\right]=\frac{THQ\times BW\times AT_n\times 365\,{}^{days}\!/_{yr}}{EF\times ED\times\left[\frac{10^{-6}\,{}^{kg}\!/_{mg}\times(IR_{soil}\times RAF_o\times SA\times M\times RAF_d)}{RfD_o}\right]+\left[\frac{IR_{air}\times(VF_{ss}+VF_p)}{RfD_i}\right]}$$

where:

THQ	=	Target hazard quotient for constituent [unitless]
BW	=	Body weight [kg]
AT_n	=	Averaging time for noncarcinogens [years]
EF	=	Exposure frequency [days/year]

ED	=	Exposure duration [years]
IR_{soil}	=	Soil ingestion rate [mg/day]
RAF_o	=	Relative oral absorption factor [unitless]
SA	=	Skin surface area [cm^2/day]
M	=	Soil to skin adherence factor [mg/cm^2]
RAF_d	=	Relative dermal absorption factor [unitless]
RfD_o	=	Oral chronic reference dose [mg/kg-day]
IR_{air}	=	Inhalation rate [m^3/day]
VF_{ss}	=	Surficial soils to ambient air partition factor (vapor) [unitless]
VF_p	=	Surficial soils to ambient air partition factor [unitless]
RfD_i	=	Inhalation chronic reference dose [mg/kg-day]

Similar to the HI calculation, the RBSL equation is solved iteratively to find C_{TPH} such that HI=1 under the constraint of a target hazard index of 1.0. Default exposure parameters are provided in Table B-1. The fraction specific RfDs are provided in Table 3-2.

Appendix C

	RESIDENTIAL SCENARIO				
Sample ID 2813057	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	2.73E+03
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	6.50E+02
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	6.56E+03
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.46E+03
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.69E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	2.29E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.20E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	1.26E+04
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.91E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	6.52E+04
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	4.39E+06
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	5.56E+05
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	7.71E+07
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	mg/kg/mg/kg)				
5-6 Aliphatics	1.82E-03	2.37E-04	5.60E-03	3.25E-05	6.85E-02
5-7 Aromatics	1.82E-03	8.53E-02	2.35E-02	9.25E-04	2.87E-01
>6-8 Aliphatics	1.34E-02	4.83E-04	1.71E-02	2.39E-04	3.93E-02
>7-8 Aromatics	1.82E-03	3.19E-02	1.04E-02	9.25E-04	1.27E-01
>8-10 Aliphatics	8.16E-02	9.73E-03	4.06E-01	6.60E-02	8.38E-02
>8-10 Aromatics	7.33E-03	9.85E-02	2.69E-02	1.59E-02	3.28E-01
>10-12 Aliphatics	4.07E-01	7.69E-04	4.17E-01	3.30E-01	1.05E-02
>10-12 Aromatics	5.41E-02	4.61E-01	3.59E-02	1.17E-01	4.99E-02
>12-16 Aliphatics	2.98E-01	1.72E-05	4.90E-02	2.41E-01	9.75E-04
>12-16 Aromatics	6.89E-02	2.95E-01	8.87E-03	1.44E-01	4.46E-03
>16-21 Aliphatics	3.19E-02	1.47E-09	6.10E-05	1.33E-03	2.96E-06
>16-21 Aromatics	9.10E-03	1.65E-02	1.37E-04	2.40E-02	1.45E-04
>21-35 Aromatics	2.28E-02	4.98E-04	2.48E-06	5.84E-02	1.08E-07
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		3.80E+03	1.67E+02	6.30E+03	102,497

	COMMERCIAL SCENARIO				
	Csat	1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05	3.82E+03
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04	9.10E+02
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05	9.18E+03
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04	2.05E+03
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04	2.36E+03
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03	3.21E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03	1.77E+04
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04	5.48E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03	9.13E+04
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05	6.14E+06
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03	7.78E+05
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03	1.08E+08
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	1.82E-03	3.94E-04	8.16E-03	3.26E-05	7.66E-02
5-7 Aromatics	1.82E-03	1.42E-01	3.42E-02	9.35E-04	3.21E-01
>6-8 Aliphatics	1.34E-02	8.04E-04	2.49E-02	2.40E-04	2.80E-02
>7-8 Aromatics	1.82E-03	5.31E-02	1.52E-02	9.35E-04	1.43E-01
>8-10 Aliphatics	8.16E-02	3.47E-03	5.90E-01	6.60E-02	5.98E-02
>8-10 Aromatics	7.33E-03	1.64E-01	3.91E-02	1.59E-02	3.24E-01
>10-12 Aliphatics	4.07E-01	2.75E-04	2.04E-01	3.29E-01	7.50E-03
>10-12 Aromatics	5.41E-02	5.05E-01	5.23E-02	1.18E-01	3.56E-02
>12-16 Aliphatics	2.98E-01	6.14E-06	1.89E-02	2.41E-01	6.96E-04
>12-16 Aromatics	6.89E-02	1.17E-01	1.29E-02	1.44E-01	3.19E-03
>16-21 Aliphatics	3.19E-02	5.25E-10	5.75E-05	1.33E-03	2.12E-06
>16-21 Aromatics	9.10E-03	1.37E-02	2.00E-04	2.40E-02	1.04E-04
>21-35 Aromatics	2.28E-02	1.78E-04	2.09E-06	5.82E-02	7.70E-08
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		1.77E+04	6.29E+02	9.31E+03	160,641

Appendix C

Sample ID 2813058	RESIDENTIAL SCENARIO Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	2.73E+03
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	6.50E+02
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	6.56E+03
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.46E+03
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.69E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	2.29E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.20E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	1.26E+04
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.91E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	6.52E+04
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	4.39E+06
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	5.56E+05
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	7.71E+07
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	mg/kg/mg/kg)				
5-6 Aliphatics	7.92E-04	1.19E-04	1.97E-03	1.48E-05	1.74E-01
5-7 Aromatics	1.98E-05	1.07E-03	2.07E-04	1.05E-05	3.74E-02
>6-8 Aliphatics	1.08E-02	4.51E-04	1.12E-02	2.02E-04	3.93E-02
>7-8 Aromatics	1.73E-04	3.51E-03	8.02E-04	9.21E-05	1.45E-01
>8-10 Aliphatics	1.26E-01	9.73E-03	5.07E-01	1.07E-01	8.38E-02
>8-10 Aromatics	1.00E-02	1.55E-01	2.96E-02	2.27E-02	4.54E-01
>10-12 Aliphatics	4.45E-01	7.69E-04	3.68E-01	3.78E-01	1.05E-02
>10-12 Aromatics	5.42E-02	5.34E-01	2.91E-02	1.23E-01	4.99E-02
>12-16 Aliphatics	2.60E-01	1.72E-05	4.51E-02	2.20E-01	9.75E-04
>12-16 Aromatics	5.88E-02	2.91E-01	6.11E-03	1.29E-01	4.46E-03
>16-21 Aliphatics	2.65E-02	1.47E-09	4.10E-05	1.16E-03	2.96E-06
>16-21 Aromatics	1.98E-03	4.14E-03	2.42E-05	5.47E-03	1.45E-04
>21-35 Aromatics	4.95E-03	4.98E-04	4.35E-07	1.33E-02	1.08E-07
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		4.39E+03	1.35E+02	6.60E+03	1,228,120

	Csat	COMMERCIAL SCENARIO 1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05	3.82E+03
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04	9.10E+02
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05	9.18E+03
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04	2.05E+03
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04	2.36E+03
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03	3.21E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03	1.77E+04
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04	5.48E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03	9.13E+04
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05	6.14E+06
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03	7.78E+05
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03	1.08E+08
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	7.92E-04	2.71E-04	2.61E-03	1.49E-05	1.25E-01
5-7 Aromatics	1.98E-05	2.44E-03	2.74E-04	1.06E-05	8.53E-02
>6-8 Aliphatics	1.08E-02	8.73E-04	1.48E-02	2.03E-04	2.80E-02
>7-8 Aromatics	1.73E-04	7.97E-03	1.06E-03	9.31E-05	3.31E-01
>8-10 Aliphatics	1.26E-01	3.47E-03	6.73E-01	1.07E-01	5.98E-02
>8-10 Aromatics	1.00E-02	3.53E-01	3.93E-02	2.28E-02	3.24E-01
>10-12 Aliphatics	4.45E-01	2.75E-04	2.04E-01	3.77E-01	7.50E-03
>10-12 Aromatics	5.42E-02	5.05E-01	3.85E-02	1.23E-01	3.56E-02
>12-16 Aliphatics	2.60E-01	6.14E-06	1.89E-02	2.20E-01	6.96E-04
>12-16 Aromatics	5.88E-02	1.17E-01	8.10E-03	1.29E-01	3.19E-03
>16-21 Aliphatics	2.65E-02	5.25E-10	5.43E-05	1.16E-03	2.12E-06
>16-21 Aromatics	1.98E-03	9.40E-03	3.20E-05	5.46E-03	1.04E-04
>21-35 Aromatics	4.95E-03	1.78E-04	5.77E-07	1.33E-02	7.70E-08
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		2.80E+04	4.63E+02	9.75E+03	3,918,639

	RESIDENTIAL SCENARIO				
	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
Sample ID 2813059		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	2.73E+03
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	6.50E+02
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	6.56E+03
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.46E+03
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.69E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	2.29E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.20E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	1.26E+04
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.91E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	6.52E+04
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	4.39E+06
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	5.56E+05
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	7.71E+07
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	mg/kg/mg/kg)				
5-6 Aliphatics	1.04E-03	1.52E-04	2.61E-03	2.00E-05	5.06E-02
5-7 Aromatics	1.04E-03	5.49E-02	1.10E-02	5.69E-04	2.12E-01
>6-8 Aliphatics	3.47E-02	1.41E-03	3.62E-02	6.67E-04	3.93E-02
>7-8 Aromatics	1.04E-03	2.05E-02	4.86E-03	5.69E-04	9.42E-02
>8-10 Aliphatics	1.19E-01	9.73E-03	4.84E-01	1.04E-01	8.38E-02
>8-10 Aromatics	9.28E-03	1.40E-01	2.77E-02	2.17E-02	4.54E-01
>10-12 Aliphatics	4.23E-01	7.69E-04	3.54E-01	3.69E-01	1.05E-02
>10-12 Aromatics	5.17E-02	4.96E-01	2.80E-02	1.21E-01	4.99E-02
>12-16 Aliphatics	2.64E-01	1.72E-05	4.61E-02	2.30E-01	9.75E-04
>12-16 Aromatics	5.62E-02	2.71E-01	5.90E-03	1.27E-01	4.46E-03
>16-21 Aliphatics	2.93E-02	1.47E-09	4.58E-05	1.32E-03	2.96E-06
>16-21 Aromatics	2.60E-03	5.29E-03	3.20E-05	7.38E-03	1.45E-04
>21-35 Aromatics	6.50E-03	4.98E-04	5.77E-07	1.80E-02	1.08E-07
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		4,277	136	6,780	132,616

		COMMERCIAL SCENARIO			
	Csat	RBSL.C.11	RBSL.C.16	RBSL.C.18	RBSL.C.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05	3.82E+03
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04	9.10E+02
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05	9.18E+03
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04	2.05E+03
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04	2.36E+03
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03	3.21E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03	1.77E+04
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04	5.48E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03	9.13E+04
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05	6.14E+06
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03	7.78E+05
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03	1.08E+08
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	1.04E-03	2.57E-04	3.38E-03	2.01E-05	7.66E-02
5-7 Aromatics	1.04E-03	9.26E-02	1.42E-02	5.75E-04	3.21E-01
>6-8 Aliphatics	3.47E-02	8.73E-04	4.69E-02	6.70E-04	2.80E-02
>7-8 Aromatics	1.04E-03	3.46E-02	6.29E-03	5.75E-04	1.43E-01
>8-10 Aliphatics	1.19E-01	3.47E-03	6.27E-01	1.04E-01	5.98E-02
>8-10 Aromatics	9.28E-03	2.37E-01	3.59E-02	2.17E-02	3.24E-01
>10-12 Aliphatics	4.23E-01	2.75E-04	2.04E-01	3.69E-01	7.50E-03
>10-12 Aromatics	5.17E-02	5.05E-01	3.62E-02	1.21E-01	3.56E-02
>12-16 Aliphatics	2.64E-01	6.14E-06	1.89E-02	2.30E-01	6.96E-04
>12-16 Aromatics	5.62E-02	1.17E-01	7.63E-03	1.27E-01	3.19E-03
>16-21 Aliphatics	2.93E-02	5.25E-10	5.75E-05	1.32E-03	2.12E-06
>16-21 Aromatics	2.60E-03	8.92E-03	4.15E-05	7.37E-03	1.04E-04
>21-35 Aromatics	6.50E-03	1.78E-04	7.47E-07	1.79E-02	7.70E-08
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.C.11	RBSL.C.16	RBSL.C.18	RBSL.C.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		20,204	457	10,019	281,187

	RESIDENTIAL SCENARIO				
Sample ID 2813060	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	2.73E+03
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	6.50E+02
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	6.56E+03
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.46E+03
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.69E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	2.29E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.20E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	1.26E+04
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.91E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	6.52E+04
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	4.39E+06
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	5.56E+05
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	7.71E+07
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	1.03E-03	1.45E-04	2.48E-03	1.96E-05	5.06E-02
5-7 Aromatics	1.03E-03	5.24E-02	1.04E-02	5.58E-04	2.12E-01
>6-8 Aliphatics	1.27E-02	4.95E-04	1.27E-02	2.41E-04	3.93E-02
>7-8 Aromatics	1.03E-03	1.96E-02	4.61E-03	5.58E-04	9.42E-02
>8-10 Aliphatics	1.34E-01	9.73E-03	5.17E-01	1.15E-01	8.38E-02
>8-10 Aromatics	9.21E-03	1.34E-01	2.63E-02	2.12E-02	4.54E-01
>10-12 Aliphatics	4.42E-01	7.69E-04	3.52E-01	3.79E-01	1.05E-02
>10-12 Aromatics	5.50E-02	5.06E-01	2.84E-02	1.27E-01	4.99E-02
>12-16 Aliphatics	2.44E-01	1.72E-05	4.08E-02	2.10E-01	9.75E-04
>12-16 Aromatics	5.85E-02	2.70E-01	5.86E-03	1.30E-01	4.46E-03
>16-21 Aliphatics	3.62E-02	1.47E-09	5.39E-05	1.60E-03	2.96E-06
>16-21 Aromatics	3.03E-03	5.91E-03	3.56E-05	8.48E-03	1.45E-04
>21-35 Aromatics	2.59E-03	4.98E-04	2.19E-07	7.04E-03	1.08E-07
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		4.10E+03	1.30E+02	6.68E+03	133,308

		COMMERCIAL SCENARIO			
	Csat	1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05	3.82E+03
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04	9.10E+02
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05	9.18E+03
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04	2.05E+03
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04	2.36E+03
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03	3.21E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03	1.77E+04
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04	5.48E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03	9.13E+04
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05	6.14E+06
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03	7.78E+05
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03	1.08E+08
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	1.03E-03	2.56E-04	3.17E-03	1.97E-05	7.66E-02
5-7 Aromatics	1.03E-03	9.23E-02	1.33E-02	5.64E-04	3.21E-01
>6-8 Aliphatics	1.27E-02	8.73E-04	1.62E-02	2.42E-04	2.80E-02
>7-8 Aromatics	1.03E-03	3.45E-02	5.90E-03	5.64E-04	1.43E-01
>8-10 Aliphatics	1.34E-01	3.47E-03	6.61E-01	1.15E-01	5.98E-02
>8-10 Aromatics	9.21E-03	2.36E-01	3.36E-02	2.12E-02	3.24E-01
>10-12 Aliphatics	4.42E-01	2.75E-04	2.04E-01	3.79E-01	7.50E-03
>10-12 Aromatics	5.50E-02	5.05E-01	3.64E-02	1.27E-01	3.56E-02
>12-16 Aliphatics	2.44E-01	6.14E-06	1.89E-02	2.10E-01	6.96E-04
>12-16 Aromatics	5.85E-02	1.17E-01	7.50E-03	1.30E-01	3.19E-03
>16-21 Aliphatics	3.62E-02	5.25E-10	5.75E-05	1.61E-03	2.12E-06
>16-21 Aromatics	3.03E-03	1.04E-02	4.56E-05	8.46E-03	1.04E-04
>21-35 Aromatics	2.59E-03	1.78E-04	2.80E-07	7.02E-03	7.70E-08
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		2.03E+04	4.31E+02	9.87E+03	282,655

Appendix C

	RESIDENTIAL SCENARIO				
Sample ID 2813061	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	2.73E+03
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	6.50E+02
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	6.56E+03
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.46E+03
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.69E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	2.29E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.20E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	1.26E+04
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.91E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	6.52E+04
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	4.39E+06
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	5.56E+05
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	7.71E+07
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	5.52E-04	8.33E-05	1.45E-03	1.05E-05	5.06E-02
5-7 Aromatics	5.52E-04	3.00E-02	6.08E-03	2.98E-04	2.12E-01
>6-8 Aliphatics	5.82E-03	2.43E-04	6.34E-03	1.10E-04	3.93E-02
>7-8 Aromatics	5.52E-04	1.12E-02	2.70E-03	2.98E-04	9.42E-02
>8-10 Aliphatics	1.15E-01	9.73E-03	4.87E-01	9.89E-02	8.38E-02
>8-10 Aromatics	7.95E-03	1.24E-01	2.49E-02	1.83E-02	4.54E-01
>10-12 Aliphatics	4.45E-01	7.69E-04	3.89E-01	3.83E-01	1.05E-02
>10-12 Aromatics	5.18E-02	5.13E-01	2.93E-02	1.19E-01	4.99E-02
>12-16 Aliphatics	2.56E-01	1.72E-05	4.68E-02	2.20E-01	9.75E-04
>12-16 Aromatics	6.06E-02	3.01E-01	6.65E-03	1.35E-01	4.46E-03
>16-21 Aliphatics	4.83E-02	1.47E-09	7.88E-05	2.14E-03	2.96E-06
>16-21 Aromatics	4.65E-03	9.75E-03	5.99E-05	1.30E-02	1.45E-04
>21-35 Aromatics	3.45E-03	4.98E-04	3.20E-07	9.41E-03	1.08E-07
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		4.41E+03	1.43E+02	6.70E+03	250,033

		COMMERCIAL SCENARIO			
	Csat	1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05	3.82E+03
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04	9.10E+02
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05	9.18E+03
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04	2.05E+03
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04	2.36E+03
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03	3.21E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03	1.77E+04
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04	5.48E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03	9.13E+04
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05	6.14E+06
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03	7.78E+05
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03	1.08E+08
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	5.52E-04	1.81E-04	1.99E-03	1.05E-05	7.66E-02
5-7 Aromatics	5.52E-04	6.53E-02	8.36E-03	3.01E-04	3.21E-01
>6-8 Aliphatics	5.82E-03	5.29E-04	8.73E-03	1.11E-04	2.80E-02
>7-8 Aromatics	5.52E-04	2.44E-02	3.71E-03	3.01E-04	1.43E-01
>8-10 Aliphatics	1.15E-01	3.47E-03	6.71E-01	9.88E-02	5.98E-02
>8-10 Aromatics	7.95E-03	2.70E-01	3.42E-02	1.84E-02	3.24E-01
>10-12 Aliphatics	4.45E-01	2.75E-04	2.04E-01	3.83E-01	7.50E-03
>10-12 Aromatics	5.18E-02	5.05E-01	4.04E-02	1.20E-01	3.56E-02
>12-16 Aliphatics	2.56E-01	6.14E-06	1.89E-02	2.20E-01	6.96E-04
>12-16 Aromatics	6.06E-02	1.17E-01	9.15E-03	1.35E-01	3.19E-03
>16-21 Aliphatics	4.83E-02	5.25E-10	5.75E-05	2.15E-03	2.12E-06
>16-21 Aromatics	4.65E-03	1.37E-02	8.24E-05	1.30E-02	1.04E-04
>21-35 Aromatics	3.45E-03	1.78E-04	4.41E-07	9.37E-03	7.70E-08
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		2.69E+04	5.08E+02	9.90E+03	530,149

	RESIDENTIAL SCENARIO				
Sample ID 2813062	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	2.73E+03
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	6.50E+02
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	6.56E+03
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.46E+03
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.69E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	2.29E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.20E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	1.26E+04
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.91E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	6.52E+04
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	4.39E+06
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	5.56E+05
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	7.71E+07
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	3.09E-03	3.31E-04	1.22E-02	5.00E-05	6.95E-02
5-7 Aromatics	3.09E-03	1.19E-01	5.14E-02	1.42E-03	2.92E-01
>6-8 Aliphatics	3.09E-03	9.16E-05	5.09E-03	5.00E-05	2.89E-02
>7-8 Aromatics	3.09E-03	4.45E-02	2.28E-02	1.42E-03	1.29E-01
>8-10 Aliphatics	5.43E-02	9.73E-03	3.48E-01	3.98E-02	8.38E-02
>8-10 Aromatics	1.24E-02	1.37E-01	5.83E-02	2.43E-02	3.31E-01
>10-12 Aliphatics	2.99E-01	7.69E-04	3.95E-01	2.20E-01	1.05E-02
>10-12 Aromatics	5.21E-02	3.65E-01	4.45E-02	1.02E-01	4.99E-02
>12-16 Aliphatics	2.72E-01	1.72E-05	4.90E-02	2.00E-01	9.75E-04
>12-16 Aromatics	8.09E-02	2.85E-01	1.34E-02	1.54E-01	4.46E-03
>16-21 Aliphatics	1.08E-01	1.47E-09	1.49E-04	4.09E-03	2.96E-06
>16-21 Aromatics	3.09E-02	3.85E-02	6.01E-04	7.38E-02	1.45E-04
>21-35 Aromatics	7.72E-02	4.98E-04	5.41E-06	1.80E-01	1.08E-07
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		3.13E+03	2.15E+02	5.71E+03	61,327

		COMMERCIAL SCENARIO			
	Csat	1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05	3.82E+03
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04	9.10E+02
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05	9.18E+03
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04	2.05E+03
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04	2.36E+03
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03	3.21E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03	1.77E+04
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04	5.48E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03	9.13E+04
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05	6.14E+06
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03	7.78E+05
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03	1.08E+08
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)				
5-6 Aliphatics	3.09E-03	4.30E-04	1.71E-02	5.02E-05	7.66E-02
5-7 Aromatics	3.09E-03	1.55E-01	7.18E-02	1.44E-03	3.21E-01
>6-8 Aliphatics	3.09E-03	1.19E-04	7.11E-03	5.02E-05	2.80E-02
>7-8 Aromatics	3.09E-03	5.79E-02	3.19E-02	1.44E-03	1.43E-01
>8-10 Aliphatics	5.43E-02	3.47E-03	4.86E-01	3.98E-02	5.98E-02
>8-10 Aromatics	1.24E-02	1.77E-01	8.15E-02	2.44E-02	3.24E-01
>10-12 Aliphatics	2.99E-01	2.75E-04	2.04E-01	2.20E-01	7.50E-03
>10-12 Aromatics	5.21E-02	4.74E-01	6.23E-02	1.03E-01	3.56E-02
>12-16 Aliphatics	2.72E-01	6.14E-06	1.89E-02	2.00E-01	6.96E-04
>12-16 Aromatics	8.09E-02	1.17E-01	1.87E-02	1.54E-01	3.19E-03
>16-21 Aliphatics	1.08E-01	5.25E-10	5.75E-05	4.10E-03	2.12E-06
>16-21 Aromatics	3.09E-02	1.37E-02	8.40E-04	7.37E-02	1.04E-04
>21-35 Aromatics	7.72E-02	1.78E-04	2.09E-06	1.79E-01	7.70E-08
Total	1.00E+00				
	SV in Calculation based on 1.0 percent foundation cracks				
		1.10E+01	1.60E+01	1.80E+01	RBSL.C.16
		s lch	s v in	ss	s v out
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI		1.00E+00	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg		1.14E+04	7.78E+02	8.44E+03	94,666